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UPPER CARBONIFEROUS CRINOIDS FROM THE MORROW SUBSERIES OF ARKANSAS, OKLAHOMA, AND TEXAS

RAYMOND C. MOORE AND FREDERICK B. PLUMMER

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INTRODUCTION

Crinoids are an extremely important element in many Lower Carboniferous faunas but appear to be comparatively rare fossils in Upper Carboniferous rocks. Weller (1898) recorded as described from Lower Carboniferous formations in North America 29 genera and 557 species of Camerata, 29 genera and 361 species of Inadunata, and 7 genera and 57 species of Flexibilia, making a total of 65 genera and 975 species of these three groups of crinoids. From the Upper Carboniferous rocks of North America were then recorded 1 genus and 1 species of Camerata, 12 genera and 45 species of Inadunata, and no Flexibilia, a total of 13 genera and 46 species. This makes clear the disparity in the development of crinoids, at least as regards kinds known, in the strata respectively classed as Mississippian and Pennsylvanian. The 40 years since publication of Weller's list has made no essential change, for in this period the additions to knowledge of North American Upper Carboniferous crinoids include (exclusive of micro-crinoids recently described by J. M. Weller) only 2 new genera and 13 species of Inadunata and 1 genus and 1 species of Flexibilia.

Crinoidal remains are actually relatively abundant in most Pennsylvanian marine deposits of North America. Many beds are highly crinoidal, containing segments of stems, disassociated plates of calices, and ossicles of arms. Complete specimens of crinoid calices are uncommon, however, in Pennsylvanian and Permian rocks. This is witnessed by the scarcity of such fossils in most paleontologic collections, even those of institutions having the most comprehensive assemblages of Pennsylvanian and Permian fossils. Furthermore, the fact that such calices as may be seen are mostly small, and apparently of somewhat similar pattern, makes them less interesting to the general student than in the case of such crinoids as the Lower Carboniferous camerates.

It is unfortunate that this field of paleontologic study has lagged, for it appears that Pennsylvanian crinoids have definite value for stratigraphic correlation, probably not only within different parts of North America but possibly between conti-

nents. Our studies indicate that specimens of crinoid calices can be found at many horizons and localities, if intensive search is made for them, and, in addition, that the types of these crinoids commonly differ appreciably from one horizon to another. We are of the opinion that, when better known, at least certain types of very fragmentary crinoidal remains can be used with reliance in paleontologic correlation. Material now collected, which includes more than 2,500 calices of Pennsylvanian and Lower Permian crinoids from the Mid-Continent region, shows many new species which are to be described in future papers. Our viewpoint in this study is primarily that of the stratigrapher who finds promise of practical usefulness in this group of fossils.

This paper deals with crinoids of earliest Upper Carboniferous age which have been obtained from rocks classed as belonging to the Morrow subseries of the Pennsylvanian series (Moore, 1935). Our specimens have been obtained from exposures near the type locality of the subseries in northwestern Arkansas, from one small area near Muskogee in eastern Oklahoma, and from the east flank of the Llano Uplift southeast of San Saba in central Texas.

OCCURRENCE OF MORROW CRINOIDS

The Morrow beds of northwestern Arkansas comprise about 300 feet of sandstone, shale, and limestone which unconformably overlie Chester (upper Mississippian) beds. Most of the fossil crinoids from this district have been obtained from the Brentwood limestone, about 70 feet thick, which in the section measured on Hale Mountain just south of Morrow, Ark., lies 82 feet above the base of the subseries. A few specimens have been obtained from the Kessler limestone which occurs about 90 feet above the Brentwood.

In outcrops along Grand River, east of Muskogee, Okla., sandstone and shale, like that composing a considerable thickness of the lower Morrow section in Arkansas, are absent, and limestone that is considered equivalent to the Brentwood lies disconformably on the Pitkin limestone of upper Chester age. It is possible, however, that the limestone beds, identified lithologically and faunally as Morrow, may belong stratigraphically either

slightly below or slightly above the horizon of the Brentwood limestone in Arkansas. Our fossil crinoids from the Muskogee area have come from an old quarry and vicinity about 2 miles north of Fort Gibson, and from outcrops along the State highway that crosses Braggs Mountain, about 3 miles southeast of Fort Gibson. The total thickness of exposed Morrow strata from which crinoids were collected in these areas is something less than 50 feet. Most of the specimens were obtained probably less than 30 feet above the base of the Pennsylvanian series as represented in this section.

The Marble Falls limestone in north-central Texas, which has a thickness of 400 to 600 feet or more, is of Morrow age, as indicated by abundant faunal evidence. Crinoid stems and other fragments are not uncommon in some of the Marble Falls beds, but complete specimens are exceedingly rare. Two fairly complete crowns of a small species identified as *Scytalocrinus* come from a horizon apparently belonging to the upper middle part of the Marble Falls formation. This is at a locality about 15 miles southeast of San Saba, Texas.

The crinoid fauna of the Morrow beds is undoubtedly much more varied than is indicated by forms described in this paper. Such a conclusion is indicated by observation of the abundance and variety of crinoidal material in these beds and by the presence in our collection of a number of fragmentary cups that belong to undescribed species but are too poorly preserved to warrant description. Furthermore, there has been little opportunity in our work to search carefully for crinoids from the Morrow beds. From the fact that some of our new species are represented by only one or two specimens, and the experience in collecting that almost any specimen found is likely to represent a new species, it is inferred that there is yet much to learn concerning the crinoid fauna of this subseries. Difficulty is found in the location of satisfactory collecting places and especially in the hardness of the limestone containing some of the crinoids, which makes removal of specimens from the matrix almost impossible. Nevertheless, deposits of Morrow age offer an extremely interesting field for further work in the collecting and study of crinoids.

PREVIOUS WORK

The first, and as yet the only published study of Morrow faunas is that of Kirtley F. Mather, which appeared in this *Bulletin* (now *Journal of the Scientific Laboratories of Denison University*), volume 18 (1915). Mather collected extensively from the Morrow strata in the vicinity of Fayetteville, Ark., while he was located at the University of Arkansas, and he also visited several localities in northeastern Oklahoma. Fossil crinoids were only an incidental object of attention in this work, however, and it is hardly surprising to discover that Mather's study constitutes only a slight beginning as regards knowledge of the crinoid fauna from the Morrow beds in the region that furnished his collections. It is indicated elsewhere in this paper that we believe there is much future work to be done before the varied crinoid fauna of this age is reasonably well known.

Mather described three new species of Morrow crinoids, based on specimens of dorsal cups: *Cromyocrinus grandis*, *Delocrinus pentanodus*, and *Delocrinus dubius*. It is interesting to note that the holotypes of the first two species mentioned are as yet the only examples that are known. *C. grandis* is an unusually large form that is doubtfully referred to *Cromyocrinus*. *D. pentanodus* is here designated as genotype of the new genus *Utharocrinus*. Mather's *D. dubius* is one of the most common and characteristic of the Morrow crinoids; it is here assigned to the new genus *Paradelocrinus*. In addition to the three crinoids mentioned, Mather described as a new genus and species a very curious type of crinoid arm, *Stereobrachicrinus pustullosus*, which is very common in the Brentwood limestone, but up to the present time there is no evidence at all as to the type of dorsal cup that belongs with these arms. The work of Mather has been a valuable starting point for the present study.

Two very completely known crinoid species, in so far as this can be said of species represented by only one or two collected examples, have been added to the list of described Morrow crinoids by Frank Springer, who for so many years held place as leader in researches on crinoids. These species are *Zeacrinus girtyi*

and *Ulrichicrinus oklahomae*, the latter being genotype of a new genus established by Springer.

Plummer and Moore in 1922 published figures of a crinoid from the Marble Falls limestone southeast of San Saba, Texas, and Moore prepared a description, which however, was not published.

ACKNOWLEDGMENTS

We are much indebted to a number of colleagues who have made available to us for study the types of various species, and to several also, who have given or loaned to us specimens of Morrow crinoids or who have otherwise aided in making our collection. We are very grateful for this assistance. Dr. Carey Croneis, of the University of Chicago, very kindly supplied all of the numerous Upper Carboniferous crinoid and Permian types in the Walker Museum collections, which include species studied by Mather and numerous types of species, important for comparison, described by Stuart Weller and by Miller and Gurley. Dr. A. H. Sutton, of the University of Illinois, made available all of the Carboniferous types in the paleontological collections of that University, and through assistance of Dr. M. M. Leighton, Chief of the Illinois Geological Survey, made a trip to Springfield in order to search the collections of the Illinois State Museum where several additional types were found. The Illinois specimens include most of the Upper Carboniferous types of species described by Meek and Worthen and by Worthen. Dr. A. K. Miller, State University of Iowa, kindly sent us the type of *Ethelocrinus verrucosus* (White and St. John). Dr. Ray S. Bassler, U. S. National Museum, furnished plastotypes of certain species represented by types in the National Museum. Mr. James Wright, of Edinburgh, Scotland, has given a representative collection of calices from the Invertiel and Roscobie beds of Scotland, classed as belonging at the top of the Scottish Lower Carboniferous section.

We are particularly grateful to Prof C. L. Foster of Bacone College, Muskogee, Okla., who gave to us for study and description his collection of Morrow crinoids from points near Fort Gibson, this material including a number of undescribed species;

also to Mr. R. Rose who assisted Professor Foster in part of the collecting and sent us material. Prof. V. O. Tansey and Prof. D. M. Moore of the University of Arkansas, assisted us in trips to the Hale Mountain exposures of the Morrow beds and to other localities near Fayetteville. The loan by Dr. C. E. Decker, University of Oklahoma, of a beautiful specimen of *Ethelocrinus*, here made the holotype of *E. oklahomensis*, is also acknowledged with thanks.

Important aid of indirect nature, as regards investigation of Morrow crinoids, is the gift or loan of a large number of Pennsylvanian crinoids from horizons above the Morrow subseries. Material of this sort, supplementing our own collections, has furnished very valuable opportunity for comparisons. Sincere appreciation of this assistance is to be expressed to the following: E. L. Banion, Independence, Kans.; Arthur Bridwell, Baldwin, Kans.; H. A. Buehler, Rolla, Mo.; Edward Butts, Kansas City, Mo.; A. C. Carpenter, Ottawa, Kans., J. M. Jewett, Lawrence, Kans.; F. P. Kleihege, Kansas City, Mo.; L. R. Laudon, Tulsa, Okla.; Paul McGuire, Fairfax, Okla.; N. D. Newell, Madison, Wis.; H. C. Price, Ottawa, Kans.; Frank Replogle, Topeka, Kans.; Gayle Scott, Fort Worth, Texas; and Bob Stevens, Tulsa, Okla.

A grant from the funds of the Graduate Research Committee of the University of Kansas has contributed importantly to the advancement of this study by providing photographic copies of most described late Paleozoic crinoids for making an illustrated catalog of these fossils, and by providing assistance in preparing the plates that accompany this paper.

SYSTEMATIC DESCRIPTIONS

Symbols for Designation of Crinoid Plates.—For the sake of brevity in description of the structure of plates in crinoid cups the system of letter symbols that has come to be generally used in treating this group of fossils is here adopted. The development of the system is due chiefly to Bather, Wachsmuth and Springer. Proceeding upward from the base of the cup, the designation of plates is as follows: infrabasal (IB), infrabasals (IBB); basal (B), basals (BB); radial (R), radials (RR); radianal (RA);

anal plate (x); right tube plate of anal series (rt); left tube plate of anal series (lt); primibrach or primibrachs (IBr); secundibrach or secundibrachs (IIBr); a particular primibrach, counting upward from the lowermost, may be indicated by a subscript number (IBr_2, for example), and similarly secundibrachs or other brachials may be specified. Each plate of any given circlet may be designated by symbols referring to position: posterior (p), anterior (a), right posterior (rp), left posterior (lp), right anterior (ra), left anterior (la). Thus, pB indicates the posterior basal, and rpR, the right posterior radial.

Order CAMERATA Wachsmuth and Springer

Family ACROCRINIDAE Wachsmuth and Springer

Genus ACROCRINUS Yandell, 1846

This genus, characterized especially by the presence of a number of circles of plates between the radials and the two basals, has been thought to be the last representative of the camerate crinoids (Wachsmuth and Springer, 1897, p. 805). Actually, it appears that *Platycrinus* is also present in mid-Pennsylvanian and possibly higher faunas of the Mid-Continent region, as indicated by discovery of the characteristically elliptical columnar segments belonging to this or a closely allied genus. Also to be noted is the discovery of several very typical camerates in rocks considered to be Permian, in the island of Timor, Dutch East Indies (Wanner, 1916, pp. 23–66).

The structure of the calyx of *Acrocrinus* has been interpreted as indicating a very interesting reversion from a specialized, simplified calyx of the type of *Dichocrinus*, its presumed ancestor, to a primitive many-plated cystid-like form in which the several circlets of plates lack a definite plan, as is the rule among crinoids (Jaekel, 1918, p. 39; Springer, 1926, p. 41). In addition to *A. wortheni* Wachsmuth, from lower Pennsylvanian beds of Illinois, the only previously known representative of this genus in Upper Carboniferous rocks, two species are to be described from Morrow strata of northeastern Oklahoma and northwestern Arkansas. They show typically the peculiarities of the genus.

Acrocrinus pirum Moore and Plummer, n. sp.

Plate XII, figures 1a-d, 2a-d; text-figures 1, 2

Calyx small, pear-shaped, greatest diameter about one-third of height above base, narrowing markedly toward summit; base flat or gently concave. Plates smooth, not convex, adjoining to make very even contour; sutures fairly distinct but not impressed. Height of holotype, 17 mm., maximum diameter (at about 5 mm. above plane that truncates the base), 14 mm., diameter at summit of RR (computed from measurement of circumference because upper part of specimen is somewhat flattened), 4 mm. Paratype no. 45192a has the following measurements: height, 13.5 mm.; maximum diameter 10.5 mm.; diameter at summit, 4 mm. Paratype no. 45212 has a height of 10 mm., a maximum diameter of 9 mm., and diameter at summit of 4 mm. The RR of the holotype measure 3.5 to 4.0 mm. in width, and 2.0 to 2.7 mm. in height.

BB 2, very small, forming flat disk; the suture extending anteroposteriorly, diameter of basal disk 2.5 to 2.8 mm. The stem impression is round, slightly concave, 1.1 to 1.5 mm. in diameter, the outer part bearing very fine radial grooves and ridges.

RR 5, rather small, width commonly about 1.5 times height, pentagonal except in case of the aR which is hexagonal; articular facets gently concave, occupying nearly entire width of RR, divided by a low ridge into an outer and inner area, of which the former is slightly deeper and more distinctly cupped.

FIGS. 1-3. STRUCTURE OF SPECIES OF *Acrocrinus*

(*1*), Arrangement of plates in *Acrocrinus pirum*, n. sp., based on study of the holotype. (*2*) Comparison of species of *Acrocrinus*; *2a*, *A. shumardi*, the genotype species, drawing of holotype; *2b*, *A. amphora* (Chester, upper Mississippian); *2c*, *A. praecursor* (Burlington, lower Mississippian); *2d*, outline of *A. wortheni* (lower Pennsylvanian); *2e*, *A. brentwoodensis*, n. sp. (Morrow); *2f*, *A. intermedius*, (Chester); *2g*, *A. pirum*, n. sp. (Morrow). (*3*), Arrangement of plates in *Acrocrinus brentwoodensis*, n. sp. (Figs. 1, 3, ×2; Figs. 2a, 2c-g, ×1).

(*Letter symbols* correspond to those regularly used in designation of plates of crinoid cups, except for slight modification as applied to extra plates inserted between radials and basals in *Acrocrinus*: *laR*, left anterior radial, *lpR*, left posterior radial, *rpR*, right posterior radial, *raR*, right anterior radial, *aR*, anterior radial, *i*, intercalary, *x*, plate of anal series, *B*, basal).

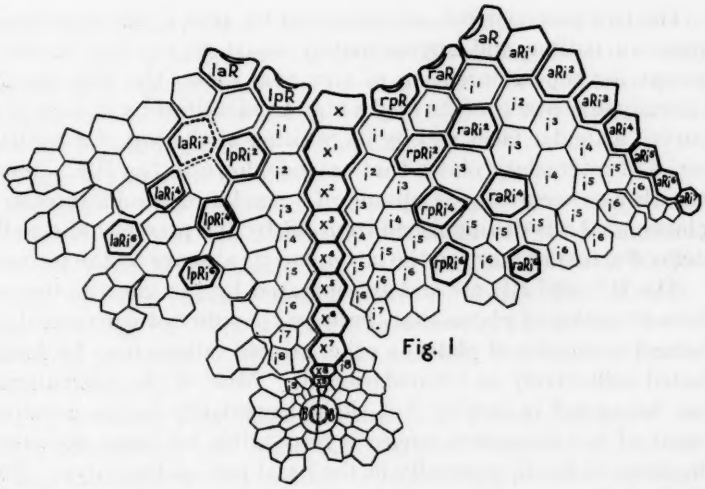


Fig. 1

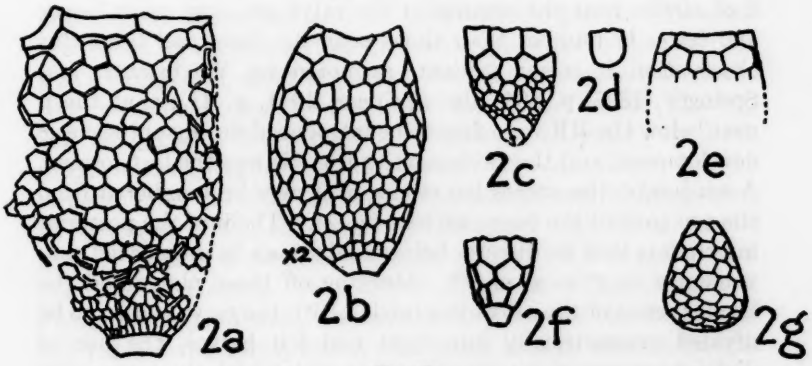


FIG. 2

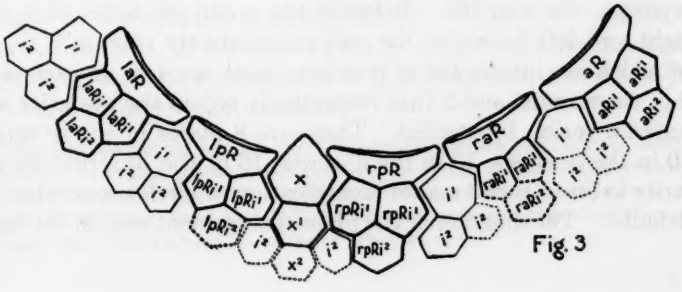


Fig. 3

The two posterior RR are separated by anal x, which is hexagonal in outline and approximately equal to the RR in size; except for the intervention of this anal plate, the RR are all laterally in contact. The anal x may be identified by its lack of a curved articular facet and by its position at the top of a regular series of intercalary plates that extends down to the BB. Since the aR also occurs at the summit of a regular series of intercalary plates, anal x is distinguished from aR by the presence of a well-defined articular facet on the latter and its absence on the former.

The RR and BB are widely separated by the intercalation of 8 to 10 circles of plates that, because they do not correspond to named categories of plates in other crinoid calices, may be designated collectively as intercalaries (ii). Most of the intercalaries are hexagonal in outline, but slight irregularity in the development of the successive circles is responsible for some deviation in shape of the ii, especially in the basal part of the calyx. The ii of circles near the summit of the calyx are very much larger and fewer in number than those near the base, and from this observation it seems evident, as noted by Wachsmuth and Springer (1897, p. 804; also Springer, 1911, p. 41), that the ii next below the RR were first to be introduced during ontogenetic development, and the circle next to the BB was the last formed. Accordingly, the successive circles of ii may be numbered from the top toward the base (see text-fig. 1). The ii of the posterior interradius that lie directly below anal x may be designated conveniently as x^1 to x^9 or x^{10}. Marking off these plates and the similar series of the aR radius (aRi^1–aRi^8), the calyx is seen to be divided symmetrically into right and left halves, the line of division between them coinciding in position with the suture that separates the two BB. Between the x and aR series of ii, the right and left halves of the calyx respectively contain 3 ii^1, all of which are interradial in position; there are 4 ii^2 on each side, 2 of them radial and 2 that respectively adjoin the posterior and anterior series, interradial. There are 8 plates in the ii^1 series, 10 in the ii^2 series, 12 in the ii^3 series, 16 in the ii^4 series; irregularity in lower series makes identification of circles somewhat indefinite. The diagram of the plate arrangement seen in the holo-

type shows clearly these features and the plan of lower circles of ii. It is chiefly to be noted that only aR among the RR is supported by a regular series of intercalary plates of such form as to suggest incorporation of part of an arm series in the calyx, which is a distinguishing feature of the Camerata.

Tegmen and arms unknown.

Remarks.—Five species of *Acrocrinus* have previously been described, all from the Carboniferous rocks of North America; four are from Mississippian beds, and one, *A. wortheni* Wachsmuth, is from lower Pennsylvanian (probably Des Moines)[1] beds (text-fig. 2). The species here described is the first one to be found in strata of Morrow age, and the first to be reported from Oklahoma.

The distinctly pear-shaped outline of *A. pirum* (Latin, *pirum*, pear) affords first and most easily applied basis for separation of this species from others now known. *A. praecursor* Springer (Burlington limestone) and *A. intermedius* Springer (Chester) are widest at the summit of the calyx; these forms possess only 2 to 4 circles of ii, and the sides of the BB slope upward from the stem attachment as in a funnel. *A. shumardi* Yandell (Chester) and *A. amphora* Wachsmuth and Springer (Chester) are both proportionately wider at the summit than *A. pirum*, have a larger number (14 to 20) of circles of ii, and BB with sloping sides; in *A. shumardi* the RR are relatively much wider than in the present species, a single R being in contact with as many as 4 ii of the first series. *A. wortheni*, from the "Coal Measures, Peoria County, Illinois," resembles *A. pirum* in the flatness of the base of the calyx, but it is a much smaller species (height and width about 5 mm.) of different outline, being approximately as wide at the summit as at mid-height. There are 6 circles of ii in *A. wortheni*, as compared with 8 to 10 in this species from Oklahoma, and the arrangement of plates appears to be different in several respects in *A. wortheni*.

[1] Worthen reports his species from "Upper Coal Measures, Peoria County, Illinois." According to information furnished by Dr. H. R. Wanless, University of Illinois, the marine Upper Carboniferous horizons of Peoria County include the St. David, Brereton, and Lonsdale limestones of Marmaton (upper Des Moines) age, and the Trivoli limestone, of lower Missouri age.

Occurrence.—Brentwood limestone, Morrow subseries, Pennsylvanian (Upper Carboniferous); Loc. 4519, Keough quarry, sec. 36, T. 16 N., R. 19 E., about 2 miles north of Fort Gibson, Okla., collected by C. L. Foster; Loc. 4521, Braggs Mountain, about 3 miles southeast of Fort Gibson, Okla., collected by R. C. Moore.

Types.—Kansas Univ., holotype, no. 45192, and paratype, no. 45192a (Loc. 4519); paratype, no. 45212 (Loc. 4521).

Acrocrinus brentwoodensis Moore and Plummer, n. sp.

Plate XII, figures 3 a-d, text figure 3

Description of this new species is based on two incomplete calices; one shows satisfactorily the entire circle of RR, anal x, and most of the upper two circles of intercalary plates; the other has several circlets of intercalaries but the top and base are missing. The holotype, which is uncrushed, appears clearly determinable as belonging to no previously described representative of *Acrocrinus*.

Calyx circular in outline at the top, diameter 13.0 mm. at summit of RR, expanding downward to base of second circle of intercalaries, diameter in this plane, about 10 mm. below top of calyx, being 16.5 mm.; outline of lower part of calyx and total height unknown.

RR short but extremely wide; the aR, which is widest, has a length of 2.5 mm. and width of 8.0 mm., and the lpR, which is narrowest, has a length of 2.5 mm. and width of 6.5 mm.; the two posterior RR are somewhat irregularly hexagonal, and the three anterior RR are irregularly heptagonal. The RR are laterally in contact except at the posterior interradius where an anal plate intervenes. Articular facets slightly inclined outward, about 2 mm. in width in the central part but expanding to 2.7 mm. near the inter-RR suture; a very narrow and low straight ridge, parallel to and near the outer face of the plate, divides an external ligament area with a short, inconspicuous ligament fossa, from the main internal part of the facet; the latter is rather obscurely divided into a central, narrowly triangular area that probably marks the articular position of a small IBr, and two

broader, slightly diverging lateral areas that are presumably the regions of contact between the radial plate and two IIBr; the peculiarity of extreme shortening of the lower elements in branching arms so that IIBr come into contact with RR is seen in the genotype and at least two other species of *Acrocrinus*.

Anal x is identifiable by its very different size and shape, as compared with other plates of the RR circle, and by its lack of an articular facet above. It is pentagonal in outline, the upper sloping margins being in contact with the posterior RR, two lower sloping margins adjoining intercalaries of the first series that underlie the posterior RR, and the squarely truncated base resting on the first intercalary of the anal series. The summit of anal x rises slightly above the line of RR. Width of this plate, 4.5 mm., length, 5.0 mm.

Beneath the RR there are several circles of intercalary plates (ii), of which only the first two are preserved in the holotype. Two ii of the first series occur below each R, all except the two plates that adjoin the anal series (the right lpRi^1 and left rpRi^1) being pentagonal; the two plates just mentioned, the first intercalary of the anal series (x^1), and five interradial ii^1 are hexagonal; there are 15 plates of the ii^1 series, including x^1. The interradial ii^1 are slightly larger than the ii^1 beneath the RR. There are 16 plates in the ii^2 circle, of which only one occurs directly in the line of each R; these plates are hexagonal, and their average size is a little smaller than that of the preceding series. The fragmentary specimen that is classed as a paratype shows several circlets of regularly hexagonal ii belonging to the mid-portion of this species, as indicated by the size of the plates and diameter of the calyx; it indicates that *A. brentwoodensis* is a moderately elongate, even-sided cup that generally resembles *A. shumardi* and *A. amphora* in outline. The lack of any impressions on the sides of the calyx furnishes ground for the conclusion that the arms were not recumbent as in *A. amphora*.

Remarks.—The only known species of *Acrocrinus* that is at all like this one from the Morrow beds is *A. shumardi* Yandell, genotype of the genus, from upper Chester strata of Kentucky. The RR of *A. shumardi* are even broader and narrower than in

A. brentwoodensis, and the arrangement of ii^1 beneath the RR is almost identical. Distinction is found in characters of the posterior region of the calyx, however, and it is almost certain that when *A. brentwoodensis* is more completely known, other differences will appear. In *A. shumardi* the anal x is broad like the RR, being in contact below with 4 plates of the ii^1 series which contains 18 plates, instead of 15, as in *A. brentwoodensis*. It is evident, however, that the present species is much more closely related to *A. shumardi* than is *A. pirum*.

Occurrence.—Brentwood limestone, Morrow subseries, Pennsylvanian (Upper Carboniferous); Loc. 4526, road cut on U. S. highway 71, about 1 mile north of bridge just west of highway, where side road leads to Woolsey, Ark., that is, about 1.5 miles northeast of Woolsey; Loc. 4524, on highway 71 about 2 miles northeast of Woolsey; both collected by R. C. Moore.

Types.—Kansas Univ., holotype, no. 45261 (Loc. 4526), paratype no. 45241 (Loc. 4524).

Order FLEXIBILIA Zittel

This division of the crinoids has become recognized as a branch of Paleozoic age, related to the inadunates, also of Paleozoic age, on the one hand, and to Mesozoic and Cenozoic articulates on the other. The Flexibilia are characterized by the loose, muscular articulation between plates of the calyx and likewise of the arms, and by lateral union of brachials by interbrachials or by a finely plated skin; IBB 3, or exceptionally fused.

Study of the Morrow crinoids in our collection indicates that certain forms of these belong among the Flexibilia. This is indicated primarily by the nature of the sutures between the plates of the calyx, and also by the articular facets of the RR.

Suborder SAGENOCRINOIDEA Wachsmuth and Springer

The posterior interradius, among sagenocrinoids, is characterized by incorporation of the first anal plate as a part of the calyx, adjoining pB, generally without development of an anal tube, or the posterior interradius may not be differentiated.

Family LECANOCRINIDAE Springer

This family, which comprises some of the less obviously modified members of the order, is characterized by the relative importance of the IBB in forming an essential part of the calyx wall, and by the generally short, rotund form of the crown. A RA is present in most of the genera, but is absent in some. Among our Morrow crinoids there are two species that appear to belong to the Sagenocrinoidea and that are placed in the Lecanocrinidae; these species belong to *Cibolocrinus*, a genus previously regarded as belonging to the Poteriocrinitidae among the Inadunata.

Genus CIBOLOCRINUS Weller, 1909, emend.

Moore and Plummer

Original definition.—Study by Weller of a very interesting assemblage of Permian crinoids from western Texas led to definition by him of a genus called *Cibolocrinus*, described as follows (Weller, 1909, p. 630):

> Dorsal cup basin-shaped or turbinate. Underbasal plates three, two large and one small, the larger plates formed by the fusion of the right and left pairs. Basal plates large, the anterior pair hexagonal in outline, the right and left postero-lateral ones pentagonal, the posterior one heptagonal. Radial plates large, wider than high, pentagonal in outline, the distal faces supplied with strong articular ridges. Anal plate small, resting between the posterior radials upon the distal extremity of the posterior basal, its distal extremity extending beyond the radials. Radianal plate absent.

As genotype, Weller designated the new species *Cibolocrinus typus*. The chief distinguishing features of the genus were considered to be the presence of 3 IBB and the absence of a RA. Although not included in the generic diagnosis, Weller noted (1909, p. 632) that in all but one of his specimens, the small IB was situated in the anterior radius. Illustrations of the genotype show clearly a slightly depressed stem impression that is circular and that hence indicates a round stem; arms and tegmen unknown.

Inspection of the species of *Cibolocrinus* described by Weller shows two types of calyx form. One of these is low basin-shaped, with IBB not visible in side view of the calyx; it is well illustrated

in the genotype, *C. typus* Weller, but not in any other of the Texas species. The other form is very distinctly conical, with IBB clearly visible from the side; it is apparent in *C. texanus* Weller, *C. symmetricus* Weller, and *C. turbinatus* Weller.

Emendation by Wanner.—Studies of the rich fauna of Permian crinoids from Timor by Wanner (1916, 1924) have led to knowledge of additional species assigned to *Cibolocrinus*, one of which, *C. transitorius* Wanner, introduces a third form of calyx. This closely resembles *Delocrinus*, differing from the two previously mentioned forms in the greater flatness of the calyx and especially in the comparatively strong depression of the base; this depression not only affects the IBB, which are naturally quite invisible from the side, but the proximal portion of the BB. All of these crinoids, from America and Timor, are distinguished by the presence of 3 IBB and of a single anal plate, although, as observed in some species from both regions, there is a tendency for the anal x to be pressed upward out of the dorsal cup.

Wanner (1916, p. 206) observed that the position of the small IB is not uniform in the various species that seem otherwise properly referable to *Cibolocrinus*, and accordingly he emended Weller's generic diagnosis to exclude consideration of the position of the small IB as an element of generic significance. He differentiated three groups within the genus on this character, however: (1) the *C. typus* group, with the small IB in the anterior radius, known only from the Permian of Texas, where, in addition to *C. typus*, it is represented by *C. texanus* and *C. turbinatus* (including *C. symmetricus* Weller which he considered as synonym of this species); (2) the *C. transitorius* group, with position of small IB not entirely constant but tending strongly to occur in the right posterior radius, known only from the Permian of Timor where it is represented by *C. transitorius* and C. *minimus*; and (3) the *C. propinquus* group, in which the small IB occurs constantly in the left posterior radius, represented by *C. propinquus* and *C. jonkeri* from the Permian of Timor. Wanner indicates that he was at first strongly disposed to erect new genera to include the second and third groups, as indicated above, but he concluded finally that such procedure was unwise. We

agree with Wanner in this judgment. Reduction in the number of IBB is undoubtedly a valid basis for generic separation but it does not appear that the distribution of the large and small plates can be accepted as ground for definition of genera.

Evidences of composite character of the genus.—Returning to consideration of form of calyx, there are grounds for the conclusion that *Cibolocrinus*, as conceived until now, embraces at least two, and probably three genetically distinct lines. In the first place, study of many hundreds of crinoids from the Carboniferous and Permian rocks of North America, including some scores of described and undescribed species, has indicated strongly that general form of the calyx is one of the most persistent and significant of all generic features. Evolutionary trends affecting the shape and position of anal plates and modifying the plan of IBB may be observed in many instances where distinctive features of calyx form remain unaltered. Structure and arrangement of the arms are extremely important generic characters, and accordingly, the nature of the articular surfaces at the summit of the calyx may be considered especially significant in study of generic relationships of crinoid calices. Proof of the general validity of these conclusions is afforded in observations made by Wanner on several different groups of Timor crinoids in which distinctive peculiarities of each, as pointed out by him, allow no room for doubt as to correctness of specific identifications; it is also given in our own study of variation in certain forms where no question can exist as to specific determination of the specimens in hand. At very least, it seems reasonable to judge that in any case where noteworthy variation in form of calyx occurs among species that are assigned to a certain genus, strong proof is required to establish the correctness of this latitude in the generic diagnosis.

As has been noted, the genotype of *Cibolocrinus* differs in form of calyx from all other species that have been referred to this genus. In addition, it is especially to be observed that the appearance of the articular facets of the genotype are quite unlike those of any of the other species that are regarded as belonging to *Cibolocrinus*. The facets of *C. typus* are very narrow, no wider

than the thickness of the radial plates; there is no well marked thickening of the summit of the radials, extending inward and constricting the opening at the top of the cup that leads to the body cavity. The general surface of the facet is rather strikingly plane, the median part as elevated as any other. The lateral parts of the facet are depressed so that in the area of each interradial suture there is a shallow flat-bottomed bowl that has a clearly defined external lip but only a faint internal border.

In evident contrast to all these features, is the nature of the articular facets in *C. turbinatus* and all other described forms (doubtless including *C. texanus*, though only one incomplete facet is shown on the holotype which is the only known specimen). The facets of this group closely resemble those of typical *Delocrinus*. The articular surface extends broadly inward from the outer margin of the radial plates, notably constricting the aperture to the body cavity; the muscle area that lies on the inner side of the transverse ridge is depressed centrally and the areas adjoining the interradial suture are more or less strongly elevated to form ridges that project radially inward at or near the position of the suture; the median inner border of the facet is moderately or strongly notched; there is a tendency for the general surface of the facet to slope outward (strongly in *C. jonkeri*), whereas this slope is inward in *C. typus*. The arm structure is not known in any species referred to *Cibolocrinus*, but characters of the arms are to some degree indicated in the nature of the articular facets. Therefore, these differences in the articular facets, combined with those in the form of cup, are quite sufficient to raise doubt as to the propriety of including all in a single genus.

Two new species of Morrow crinoids, that are clearly referable to *Cibolocrinus*, as indicated by the presence of only 3 IBB and a single anal plate, are of special interest in view of the preceding discussion of the relations between form of cup and articular facets. The new species agree in every particular with *C. typus* except that in one of the Morrow forms the small IB is located in the right posterior radius instead of the anterior; they resemble other species that have been referred to *Cibolocrinus* only in re-

spects that these correspond to *C. typus*, which do not include form of calyx or nature of the articular facets. This observation applies equally to another new species, represented by several specimens from different localities in the Plattsburg and Stanton limestones, belonging near the top of the Missouri subseries (upper middle Pennsylvanian); the Missouri form belongs definitely to the group of *C. typus*, thinness of the articular facets being one of its outstanding characters.

Restriction of Cibolocrinus.—We are convinced of the need to revise conception of *Cibolocrinus* so as to include in it only forms that agree with the genotype in general configuration of the calyx, the IBB not being visible from the side, and having articular facets of the type observed in *C. typus*. A feature that is common to *C. typus* and all of the new Pennsylvanian species in our collection, is the slight but sharp impression of the stem beneath the otherwise nearly plane surface of the IBB disk; this is not at all the same as the concavity seen at the base of the turbinate calices, nor does it correspond in any way to the invagination of the base of *C. transitorius*.

For the conical calices in which IBB are plainly visible from the side and in which the articular facets are of the *Delocrinus* type, the new generic name *Stuartwellercrinus* is proposed (see following), with *Cibolocrinus turbinatus* Weller as genotype. The stock from which *Stuartwellercrinus* was derived is believed to be entirely different from that which produced *Cibolocrinus*; indeed, evidence is now at hand to show that *Cibolocrinus* was existent in typical form at least as early as near the beginning of Upper Carboniferous time, while no representative of *Stuartwellercrinus* older than Late Permian is yet known.

The species called *C. transitorius* corresponds to two of the new Pennsylvanian forms of true Cibolocrinus in having the small IB in the right posterior radius, although this is very inconstant in the Timor species. This is not considered a feature of significant similarity that indicates relationship. *C. transitorius* resembles *Stuartwellercrinus* in the nature of the articular facets and in other characters that led to former inclusion of both in *Cibolocrinus*. The form of the calyx is like that of *Delocrinus*,

and it seems not impossible that *C. transitorius* was derived out of *Delocrinus*. Since this *Delocrinus*-like species can be referred neither to *Cibolocrinus* nor to *Stuartwellercrinus*, as these are here defined, it appears necessary to erect a new genus to receive it. The name *Paraplasocrinus* is proposed, with *C. transitorius* as genotype and at present the only known representative.

Emended diagnosis of Cibolocrinus.—Summarizing features of the foregoing discussion, it is desirable to formulate a revised statement of the characters of *Cibolocrinus* as here restricted. Chief importance in this emended definition is attached to the form of the calyx and the nature of the articular facets which surely reflect characters of the arms that are unlike those of common poteriocrinids.

Calyx basin-shaped, with evenly rounded or flat base, dicyclic, IBB not visible from the side, stem impression round, slightly but sharply depressed. IBB 3, position of small IB variable but generally in anterior or right posterior radius. BB 5, pB typically somewhat larger than others. RR 5, bearing narrow articular facets that are not appreciably wider than the thickness of the radial plates, with a well-defined broad furrow at the sides, the confluent furrows on adjoining plates making a crescent-shaped basin in the area of the interradial sutures. Anal x moderately large, separating the posterior RR and resting on pB. Arms unknown.

Genotype, *Cibolocrinus typus* Stuart Weller, from the Cibolo limestone, Upper Permian, Presidio County, Texas. The syntypes of this species are Univ. Chicago Walker Museum, no. 13370.

As restricted, this genus is now known only from the Upper Carboniferous of Oklahoma and Kansas, and from the Upper Permian of western Texas.

Classificatory position of Cibolocrinus.—The study of the proper definition of *Cibolocrinus* was largely completed before attention was called to the possibility that this genus might belong to a crinoid family other than the Poteriocrinitidae where it has been placed by all authors. Question was first raised in connec-

tion with examination of the articular facets. Later, it was observed that although some of the suture faces of calyx plates in Morrow species of *Cibolocrinus* are nearly plane, there is actually a very common and characteristic difference between them and other crinoid plates from these beds. The sutures tend to be excavated more or less strongly, and on this character it is possible readily to separate loose *Cibolocrinus* plates from others, identification being checked by comparison with corresponding plates of complete calices. Since this type of suture indicates the sort of ligamentous union of plates that is a feature of the Flexibilia, rather than of the Inadunata, although it may be developed moderately in some of the latter, comparison was made with various representatives of the Flexibilia. Although most of these, especially forms with arms attached to the dorsal cup, appear not to resemble the calyx of *Cibolocrinus*, it was noted immediately that such genera as *Lecanocrinus* and some species of *Asaphocrinus* and *Mespilocrinus*, which are members of the family Lecanocrinidae, are not at all unlike *Cibolocrinus*. We find here almost exactly duplicated the type of articular facets of the RR which are seen in *C. typus* and which initially led to our question concerning the assignment of certain species to this genus. The structure of the IBB circlet of *Cibolocrinus*, consisting of two large plates and one small one, is that of all Flexibilia (with unimportant exceptions), and if other known characters agree better with diagnostic features of the Flexibilia than with the Inadunata, it seems proper to regard the 3-plated IBB circlet of *Cibolocrinus* as a mark of membership in this order rather than a sign of evolutionary specialization of a poteriocrinid. It should be noted parenthetically that although the right posterior position of the small IB in *C. tumidus* from the Morrow and a new species from Missouri beds is the same as is the rule among Flexibilia, this plate occurs in the anterior radius in *C. typus* and *C. regularis*; similar exceptions occur in the Flexibilia (Springer, 1920, p. 454). All things considered, little hesitation is felt in transferring *Cibolocrinus*, as emended, to a place in the family Lecanocrinidae among the Flexibilia.

Cibolocrinus tumidus Moore and Plummer, n. sp.

Plate XII, figures 4a-e; text-figure 4

Calyx shaped like a flat-bottomed bowl with uneven sides, due to the somewhat bulbous outline of the plates; regularly circular in outline at top; diameter at summit of RR of the holotype and three paratypes, respectively, measures 21 mm., 20 mm., 19 mm., and 19 mm.; diameter of nearly flat basal area in each, about 14 to 15 mm.; height of calyx in holotype, 10 mm., paratypes, 9 mm.; the sides of the calyx appear entirely symmetrical in lateral view that is directed toward the center of any of the RR or pB, but turned slightly from this so as to bring into view the profile of a bulging R on one side of the calyx, the opposite side which is located at or near an interradial suture appears to slope much more steeply.

IBB 3, unequal, the smallest plate being located in the right posterior radius; the distal margin of the two larger plates is almost a straight line, whereas the angles at ends of the inter-IBB sutures are distinct; plane of the IBB disk nearly flat, but a central circular area, 5.5 mm. in diameter is sharply depressed about 1 mm. to receive the proximal stem segment.

BB 5, equal, except for the slightly larger size of pB which is widened to carry at its truncated upper margin the fairly large anal x; plates strongly and evenly convex, the proximal part of each lying in the plane of the IBB which also is the plane of the base of the calyx, the distal part of each nearly at right angles to the basal plane; curvature to the lateral margins of the plates makes the position of the sutures very evident, but the sutures are not impressed. The pB is heptagonal, the other BB hexagonal, although lpB and raB, which adjoin the large IBB, appear almost pentagonal.

RR 5, pentagonal, nearly twice as wide as long except in case of lpR and rpR which are narrowed to provide space for the large anal x between them; surface rather strongly and evenly convex, greatest bulge being located centrally on each plate so that the surface near the summit slopes inward as well as upward; the inter-RR sutures are nearly vertical but slope slightly outward.

Articular facets, which are rather unusually well preserved in the holotype, narrow, not wider than the thickness of the radial plates, which is about 2.5 mm.; facets separated from the outer surface of plates by a sharp angulation, which, as viewed from above, bends outward distinctly near the interradial sutures, and more gently outward in the mid-section of the plate; beginning about 1.5 mm. distant from the interradial sutures and joining the marginal angulation is a narrow straight cross ridge that divides the facet into an outer ligament area, 0.75 mm. wide near center, and an inner muscle area, 1.5 mm. wide near center of plate; a deep, narrow ligament groove, about 4.5 mm. in length, closely adjoins the cross ridge externally; muscle area slopes inward; laterally the muscle area of each facet develops into a widening shallow depression that is bounded externally by the cross ridge and internally by a fainter ridge, the furrow thus made on half of one face being confluent with its neighbor on the adjoining radial, the two together forming a crescent-shaped basin with maximum width, about 2.3 mm., at the interradial suture. These features of the articular facet are typical of *Cibolocrinus*, as here restricted. A noteworthy character, also, is the smooth internal border of the facet, without observable indentation of an ambulacral groove.

A comparatively large anal x, heptagonal in outline, rests broadly against the pB and for two-thirds or slightly more of its length adjoins the posterior RR; the part of the plate that projects above the line of the RR appears somewhat rounded in outline, but in well-preserved specimens shows four sutural facets, those at the top narrowing markedly; anal x, like other plates above the IBB, distinctly convex.

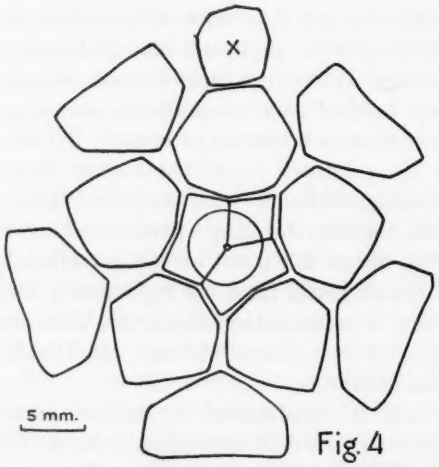
Surface of the entire cup is covered by close-set small but strong granules.

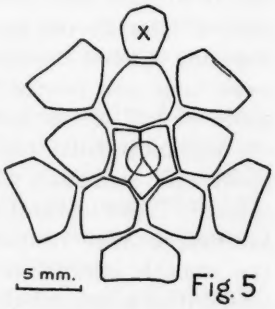
Arms and tegmen unknown.

Numerous separated RR and BB of *Cibolocrinus*, identifiable by their form, surface ornament, and, in the case of RR, the distinctive features of the articular facets, are contained in our collections from northeastern Oklahoma and northwestern Arkansas. Comparison with the types of *C. tumidus* shows that

some of these plates belong to this species. An interesting feature is the slightly hollowed suture faces which is accentuated by a sharp angle or slightly raised border at the inner edge of the plates.

Remarks.—The rounded bulge of the basal and radial plates of *C. tumidus* resembles that of some specimens of *Paraplasocrinus transitorius* (Wanner), as identified by Wanner, but the entirely different form of calyx and articular facets make this





FIGS. 4 AND 5. DIAGRAMS OF THE DORSAL CUP OF *Cibolocrinus*

(*4*), *Cibolocrinus tumidus*, n. sp., showing small infrabasal in right posterior ray. (*5*), *Cibolocrinus regularis*, n. sp., showing small infrabasal in anterior ray.

comparison of little importance. No previously described *Cibolocrinus* has the convex rounded and ornamented plates that are observed in *C. tumidus*.

Occurrence.—Brentwood limestone, Morrow subseries, Pennsylvanian (Upper Carboniferous); Loc. 4519, Keough quarry, sec. 36, T. 16 N., R. 19 E., about 2 miles north of Fort Gibson, Okla., collected by C. L. Foster and (Loc. 4520) by R. C. Moore; Loc. 4521, Braggs Mountain, about 3 miles southeast of Fort Gibson, collected by R. C. Moore; Loc. 4522, Brentwood lime-

stone on U. S. highway 71 opposite Woolsey, Ark., (separated plates), collected by R. C. Moore and F. B. Plummer.

Types.—Kansas Univ., holotype, no. 45193, and paratypes 45193a, b (Loc. 4519); paratype 45201 (Loc. 4520).

Cibolocrinus regularis Moore and Plummer, n. sp.

Plate XVI, figures 2a-d; text-figure 5

Calyx bowl-shaped, somewhat flattened on base, small, measuring 11 mm. in diameter at top, and 5.5 mm. in height, plates almost imperceptibly bulbous so that sutures lie in shallow furrows.

IBB 3, sutures in part very indistinct; careful study of crystal orientation of the calcite in different parts of the disk confirms the conclusion that a large IB lies beneath rpB, another beneath lpB, and a small IB in the anterior radius. IBB disk flat, not visible from side, the central area slightly but sharply depressed to receive a circular stem segment that is 2.5 mm. in diameter.

BB 5, the pB being distinctly larger than the others and truncated at the top for contact with a moderately large anal x; proximal part of each plate joining the IBB disk in its plane, the distal part curving to a position nearly at right angles to this plane; in addition to the convexity that gives form to the lower part of the calyx, each plate is centrally swollen so as to appear very slightly bulbous.

RR 5, pentagonal, length about two-thirds of width, laterally in contact except at posterior side where anal x intervenes. Articular facets typical for the genus, as restricted, but unlike other examples seen, the facets of this species show a well-defined pair of small but moderately deep furrows in the mid-portion of the muscle area, next to the inner margin of the facet; thickness of radial plate at summit, which also represents width of articular facet, 0.9 mm.

Anal x relatively large; it is not preserved in the holotype, but its outline (except the part above the line of RR) is clearly shown by the margins of adjoining plates; anal x increases in width upward, being 2 mm. wide at the base and 3.5 mm. wide between the tops of the adjacent RR.

Entire surface ornamented with fine granules, which are only slightly elevated.

Remarks.—Because of its approximate similarity in shape of calyx to *C. tumidus* and its association with this species, the possibility that the form here described might be an immature example of *C. tumidus* is suggested. Aside from the difference in the location of the small IB, in which *C. regularis* shows identity with *C. typus*, comparison of the two Morrow forms leaves no question as to their distinction; the outlines of the calices differ, the RR of *C. regularis* are proportionately longer, and the plates of the smaller species are very much less bulbous than in *C. tumidus*; the articular facets of the two species show slight but apparently significant differences.

Occurrence.—Brentwood limestone, Morrow subseries, Pennsylvanian, (Upper Carboniferous); Loc. 4519, Keough quarry, sec. 36, T. 16 N., R. 19 E., about 2 miles north of Fort Gibson, Okla., collected by C. L. Foster.

Type.—Holotype, Kansas Univ., no. 45195 (Loc. 4519).

Order INADUNATA Wachsmuth and Springer

Suborder FISTULATA Wachsmuth and Springer

Family POTERIOCRINITIDAE Bassler

This very important subdivision of the fistulate crinoids that has long been recognized by authors as the Poteriocrinidae, is here termed the Poteriocrinitidae. The reason for this change is the fact that the genus from which the family name is derived cannot be *Poteriocrinus* Agassiz, 1837, for this is an objective synonym of *Poteriocrinites* Miller, 1821. Despite long use of the invalid name introduced by Agassiz, it was concluded by us that there is no question under the Rules of Zoologic Nomenclature as to incorrectness of the use of *Poteriocrinus*, and hence of Poteriocrinidae, unless or until the International Commission should set aside application of the Rules. We have learned that Dr. R. S. Bassler, in preparing an index of Pelmatozoa for the Fossilium Catalogus, is discarding numerous improperly used, though common names applied to crinoids and that he is introducing the family designation Poteriocrinitidae, based on Miller's valid

generic name *Poteriocrinites*. It seems best to apply the Rules, rather than to seek uniform adoption of the "—crinus" ending for genera of crinoids, especially since this attempt would logically call for many other exceptions to the Rules.

It is our present view that the subfamilies, such as Poteriocrininae, Graphiocrininae, and Encrininae, as given by Springer (1913, pp. 222–226) are probably really not genetically significant subdivisions, but we are not prepared to suggest a different classification. The groupings by Bather (1900, pp. 179–182), Jaekel (1918, pp. 60–65), and Wanner (1924) are conflicting and in various respects unsatisfactory. It seems best procedure for the present to give no attention to questions bearing on subfamily classification. Genera are here introduced in the approximate order of their structural advancement.

SECTION I.—GENERA WITH CONICAL CUPS CONTAINING THREE ANAL PLATES

Grouped for convenience here, but without biologic classificatory designation, are forms of Morrow crinoids that exhibit the structurally more primitive characters of the Poteriocrinitidae,—a distinctly conical form of dorsal cup and the presence of three anal plates below the line of the summit of the radials. Six species that are assigned to five different genera belong here: *Hydriocrinus? rosei* Moore and Plummer, n. sp.; *Morrowcrinus fosteri* Moore and Plummer, n. gen., n. sp.; *Scytalocrinus sansabensis* Moore and Plummer, n. sp.; *Ulrichicrinus oklahomae* Springer; *Agassizocrinus magnus* Moore and Plummer, n. sp., and *A. caliculus* Moore and Plummer, n. sp.

Genus HYDRIOCRINUS Trautschold, 1867

This genus was established to include poteriocrinids with a high conical calyx, 5 IBB visible from the side, 3 anal plates below the upper limit of the RR, pentagonal stem, and with rather slender arms that branch two or more times dichotomously. It was based on a moderately small species, *Hydriocrinus pusillus* Trautschold, which is thus the genotype, from Moscovian (lower Upper Carboniferous) beds near Moscow, Russia. In addition to the characters noted, the genus is reported to have a strong

anal sac. Several specimens of *H. pusillus* from the vicinity of Moscow, loaned to us for study from collections of the University of Chicago, fail to show any distinct sign of a sac, however.

Since generic differentiation of most members of the family Poteriocrinitidae depends on characters of the arms and ventral sac as well as on features of the calyx, it is often extremely difficult to determine the true affinities of a cup having distinctive general characters of the family but lacking diagnostic structures such as arms and sac. Among our fossils from the Morrow of Oklahoma is a very interesting undescribed conical crinoid cup to which is attached the lower part of a strong ventral sac but no part of the arm structure; there are 3 anal plates in the cup, and the stem impression indicates a pentagonal column. Question is naturally raised as to the proper generic assignment for this form.

Although several calices of this general type from Upper Carboniferous rocks of North America have been referred to *Poteriocrinus* (an invalid name because it is a synonym of *Poteriocrinites* Miller, 1821), this genus is not to be considered because of the distinctly narrow and curved articular facets which characterize it,—not to mention other difference of probable importance. Other genera having typically definite cone-shaped cup are *Culmicrinus* Jaekel, *Moscovicrinus* Jaekel, *Ophiurocrinus* Jaekel, *Ulrichicrinus* Springer, and *Hydriocrinus* Trautschold; in addition, resemblance is seen to at least some species that are regarded as belonging to *Pachylocrinus* Wachsmuth and Springer, *Abrotocrinus* Miller and Gurley, and *Scytalocrinus* Wachsmuth and Springer. Of these, only *Hydriocrinus* and, according to interpretation of Springer (1926, p. 72), *Abrotocrinus* have a pentagonal column. The really essential distinguishing features of all these genera are found in the nature of arm structures and sac. Lacking knowledge of these in our specimen, it seems proper to give attention to such a feature as the shape of the stem, which is probably a significant, even though possibly an inconstant character.

The shape of the calyx and the strong plates of the ventral sac that are shown by some species classed as belonging to *Abrotocrinus* agree very well with characters of the Morrow cri-

noid under consideration. If one could accept Springer's definition of *Abrotocrinus*, which admits any pentagonal-stemmed poteriocrinid with strong sac and branching of arms like that of *Pachylocrinus*, it would seem best to identify our species as probably belonging to *Abrotocrinus*. Examination of Miller and Gurley's description and illustration of the genotype of *Abrotocrinus* (*A. cymosus* Miller and Gurley, from the Keokuk limestone of Indiana), however, shows that this species has an entirely different structure of the anal area, a rather low cup, and a stem that is only in part obscurely pentagonal. It is hard to see how Miller and Gurley's genus can be interpreted as by Springer. We are driven to regard *Hydriocrinus* as the only described genus that may be accepted tentatively as place of assignment for this new Morrow species. This is a very unsatisfactory conclusion, however, for we doubt greatly that the arms of the Morrow form, and especially the sac, correspond to those of *Hydriocrinus*. Also, in *H. pusillus* there is a well-marked horizontal line approximately even with the top of the RR that separates the three anal plates of the calyx from the higher plates of the sac; this is not observed in our specimen.

Following completion and transmittal of manuscript to the editor, opportunity has been afforded for study of the holotype of *Abrotocrinus cymosus*. The specimen, carefully freed from the matrix, proves to be a typical representative of *Pachylocrinus*, unless, as interpreted by Springer, the pentagonal nature of the stem in the proximal region is employed as a distinguishing generic character. The posterior part of the dorsal cup, showing a normal anal series, was not seen by Miller and Gurley, for it was embedded in the matrix, and they mistook the lower part of the anterior ray for an anal series. After study of the genotype and other species considered to represent *Abrotocrinus* we are not inclined to think that the form called *Hydriocrinus? rosei* should be placed in *Abrotocrinus*, chief basis for this opinion being the high conical nature of the cup in *H.? rosei* with clearly visible IBB. On the other hand, as already noted, it must be admitted that important differences from typical *Hydriocrinus* also appear.

Hydriocrinus? rosei Moore and Plummer, n. sp.

Plate XIV, figures 8a-d; plate XVI, figure 9; text-figure 6

Calyx strongly conical, with sides sloping evenly from stem attachment to summit of RR, wider than high; diameter of holotype at top of cup, about 21 mm., height, 15 mm.

IBB 5, equal, quadrangular; proximal tips bent sharply from

the slope of the side of cup, being covered by stem attachment, distal part plainly visible from side; length above stem impression, about 5.5 mm., maximum width, about 4.2 mm. The hexagonal outline of these plates as represented in analysis of the calyx (text-fig. 6) is due to foreshortening of the proximal inflected part in side view; the proximal and distal parts of inter-IBB sutures are actually in the same plane.

BB 5, nearly equal in size, pB and rpB heptagonal, others hexagonal, about 10 mm. long and 8 mm. wide.

RR 5, pentagonal, mostly wider than long, lpR and rpR being relatively narrowed by intervention of the anal series; aR measures 10 mm. in width, 7 mm. in length. Articular facets straight, occupying entire width of plates; only the outer part of the facet and the transverse ridge is seen in aR and raR, but the entire facet is visible in rpR; summits of other RR broken. The plane of the facets is nearly horizontal; outer ligament area sharply marked, being separated from outer face of plate by strong angulation, and bounded internally by the fairly prominent straight transverse ridge which bears numerous fine denticles; this ligament area is rather narrow, distinctly concave, and no clearly defined ligament pit is observable; internal ligament area fairly broad, divided obscurely into interarticular ligament fossae adjoining the transverse ridge, and muscular fossae which slope inward from the ridges at inter-RR sutures.

Three anal plates of nearly equal size form part of the dorsal cup; RA, pentagonal in outline, broadly in contact with pB and rpB, below, and supporting anal x, rt and rpR; anal x rests on the truncated edge of pB and for about two-thirds of its length adjoins lpR, the remaining third extending above the line of RR; only the lower part of rt reaches below the summit line of the RR. Several plates of the strong anal sac appear above those mentioned, showing a round tube about 10 mm. in diameter at a height of 10 mm. above the RR; between some of the plates of this tube are short slits disposed at right angles to the sutures, presumably respiratory in function.

Surface of dorsal cup and tube ornamented by a fine pattern of pits and ridges; a belt about 1.5 mm. wide at the edge of each

plate is differentiated by the subparallel arrangement of the pits following the direction of the plate margin, the remainder of the area having less definite pattern.

Stem pentagonal, at least in its proximal portion, as indicated by the stem impression which is 4.5 mm. in diameter; axial canal strongly pentalobate or stelliform, the points of the lobes being radial in position. Arms unknown.

Remarks—This distinctive, beautifully decorated crinoid corresponds closely in form to *"Poteriocrinus" macoupinensis* Worthen, from the lower Pennsylvanian of Illinois, but is about twice as large and it is ornamented rather than smooth. The Illinois form may have a pentagonal stem, but examination of the type, which has been loaned for our study, does not establish this; the character of the anal sac is not determinable in Worthen's species, nor are the arms preserved. The form and structure of the cup of *"Scaphiocrinus?" washburni* Beede, from middle Virgil beds near Topeka, Kans., also suggest *H.? rosei*. The figures of Beede's species indicate a somewhat crushed cup that has a distinctly lower IBB circle than in our form, apparently a different surface ornamentation, and a round stem; unfortunately, the type of *"S.?" washburni* appears to be lost.

Occurrence.—(?) Brentwood limestone, just north of Keough quarry, in sec. 36, T. 16 N., R. 19 E., Oklahoma, about 2 miles north of Fort Gibson (Loc. 4519). Because the specimen on which description is based was collected at the foot of a slope that contains outcrops both of the Brentwood limestone, belonging to the Morrow subseries, Pennsylvanian (Upper Carboniferous), and the underlying Pitkin limestone, of Chester age (Mississippian series, Lower Carboniferous), there is doubt as to the exact horizon from which it came. Judging by the appearance of the specimen, the common occurrence of crinoids in the Brentwood of this area, and lack of Pitkin crinoids collected here, it seems reasonable to assign this species tentatively to the Brentwood fauna.

Type.—Holotype, Kansas Univ., no. 45197; collected by R. Rose, Muskogee, Okla.

Genus MORROWCRINUS Moore and Plummer, new genus

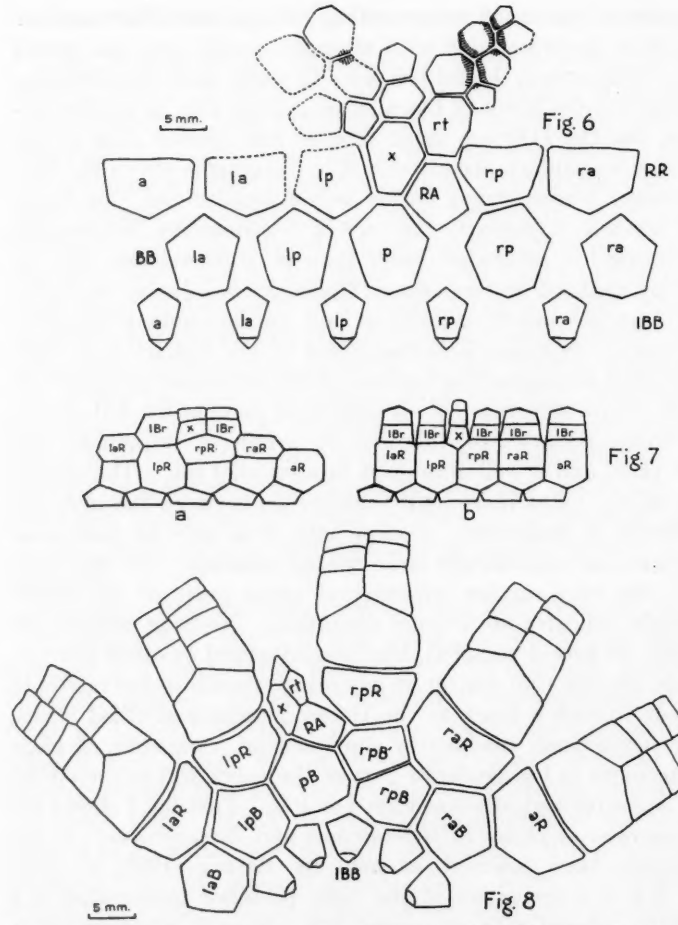
Calyx conical, height approximately equal to width, dicyclic, IBB 5, clearly visible from side. BB consisting of 4 normal plates (pB, lpB, laB, raB), and in the position of rpB, two plates which are here designated as rpB and rpB′ (see text-fig. 8). RR 5, pentagonal except small raR which is hexagonal, distinctly wider than long. Three anal plates in dorsal cup, consisting of a relatively large RA, obliquely above and at right of pB, followed above by anal x and rt, the upper parts of the two latter plates projecting slightly above RR. Radial facets nearly straight, equal to full width of RR; articular surfaces not observed. First primibrachs axillary, pentagonal in outline, slightly larger than RR, each supporting two uniserial arms with large quadrangular segments; no indication of further branching in genoholotype which preserves only lower part of arms. Stem round, with strongly pentalobate axial canal. Ventral sac apparently well developed, as indicated by cross section of it at height of about 13 mm. above calyx in the genoholotype; distal portion of sac unknown.

Genotype, *Morrowcrinus fosteri* Moore and Plummer, n. sp.

Remarks.—The calyx of this genus corresponds in general features to *Pachylocrinus* Wachsmuth and Springer, which, as currently defined, includes a somewhat heterogeneous assemblage of Lower Carboniferous and a few Upper Carboniferous crinoids with conical to low cup-shaped calices, uniserial arms branching dichotomously two to four times, strong ventral sac, and round stem. It may be doubted whether all of the species referred to *Pachylocrinus* are really congeneric. The genotype of *Pachylocrinus, P. aequalis* (Hall), from lower Mississippian (Osage) beds, has a low basin-shaped cup with arms not laterally in contact, branching three or four times dichotomously, brachials mostly strongly cuneiform, pinnules well developed. The arrangement of plates in the anal series corresponds to that observed in *Morrowcrinus*, but there is no additional plate in the position of rpB. Further, distinction appears in the arrangement of the arms, which are closely in contact all around. The

character of the arms seems mainly to separate *Morrowcrinus* from other poteriocrinids with strongly conical cup and round stem. *Culmicrinus* Jaekel has 8 to 10 wide, short primibrachs; *Woodocrinus* De Koninck has a large axillary IBr, as in *Morrowcrinus*, but the IIBr are much broader and shorter than in our form and an axillary plate occurs 4 to 8 segments above the first branching; *Moscovicrinus* Jaekel is not slender and the round arms are not in contact; the cup of *Scytalocrinus* Wachsmuth and Springer is somewhat lower than in *Morrowcrinus* and the arms are rounded and separated; *Ophiurocrinus* Jaekel has fewer arms that are nearly cylindrical and not in contact laterally; *Ulrichicrinus* Springer is distinguished by the axillary first IIBr.

The chief distinguishing features of *Morrowcrinus*, as described, consist of the occurrence of an additional plate in the BB circlet, the strong axillary IBr, followed by primitive, impinnate uniserial IIBr, and a well-developed tubular anal sac. The significance of the extra plate (rpB′) interposed between RA and rpB is difficult to determine. Conceivably, it is only an individual variation that accordingly lacks special meaning. On the other hand, the very regular structure of other parts of the crown certainly indicates no unusual distortion. Nothing comparable to rpB′, as here designated, has been observed in other poteriocrinids, nor, for that matter, in any other crinoids unless reference is made to such a stock as the Heterocrinidae and allied forms. These Ordovician inadunates show several variations of plate arrangement in the posterior part of the calyx and in the circlet that is morphologically considered as RR. Text-fig. 7 shows the arrangement of plates in *Heterocrinus* and *Ectenocrinus*. It has commonly been inferred, as held by Bather (1900, p. 147), that RA is a derivative of the right posterior infer-radial of a primitive crinoid with compound RR, although Springer (1920, p. 56), has indicated reasons for dissent from this view. If RA is a modified infer-radial of the rpR, it is worthy of note that rpB′ of *Morrowcrinus* may equally correspond to the adjoining infer-radial of the right anterior ray. Whether or not such hypothetical persistence of this extra plate may be assigned to disturbance of symmetry due to anal structure, the compound



FIGS. 6–8. DIAGRAMS OF CALYX STRUCTURE IN TWO MORROW CONICAL-CUP POTERIOCRINIDS, AND, FOR COMPARISON, TWO ORDOVICIAN HETEROCRINIDS

(*6*), *Hydriocrinus? rosei*, n. sp., a poteriocrinid of normal type having strong anal sac and pentagonal stem, Morrow. (*7*), Ordovician heterocrinids (after Bather); *7a*, *Heterocrinus*, showing compound radials in three rays; *7b*, *Ectenocrinus*, also with three compound radials. (*8*), *Morrowcrinus fosteri*, n. gen., n. sp., showing two plates in position of right posterior basal, and 10 simple uniserial arms, Morrow.

laR being fused, is a question, but it is evident that if the extra plate in *Morrowcrinus* has any relation to the plan of the cup in heterocrinids or similar forms our so-called rpB′ should be considered rather as an element of the raR. Lacking other specimens that show rpB′, it is certainly inadvisable to stress the peculiarities of this feature. Other characters that have been noted seem sufficient for generic separation of *Morrowcrinus* from known types.

Occurrence.—Morrow subseries, lower Pennsylvanian (Upper Carboniferous), northeastern Oklahoma.

Morrowcrinus fosteri Moore and Plummer, n. sp.

Plate XIII, figures 4a-d; plate XVI, figure 11; text-figure 8

This species is based on a single incomplete but, for the most part, beautifully preserved crown. It comprises the cup and the lower part of the arms to a height above the RR that is approximately equal to height of the cup. The general features are as indicated in characterization of the genus. The plates are smooth except for delicate ornamentation, and the sutures distinct but not impressed. The surface of the cup is very even in contour. Height of cup, 15.0 mm., maximum width, 18.0 mm.

IBB 5, quadrangular, although they appear hexagonal when viewed from the side (text-fig. 8); this is due to the sharp inflection, nearly at right angles, of the proximal portion of each plate that forms a segment of the stem impression, which is round and gently concave. Each IBB bears about 9 radially disposed fine ridges in the stem segment area. Length above stem impression, 4.3 mm., maximum width 4.3 mm. to 5.0 mm.; diameter of stem impression, 4.5 mm.

BB relatively large, length about equal to width; laB, lpB and raB are hexagonal although the two sutures at the proximal margin may appear almost as a straight line. The pB is octagonal, being broadly in contact above with lpR at left and RA at right, the small truncated tip of pB supporting anal x; on its right side pB broadly joins rpB′, and below this, narrowly touches rpB which is irregularly hexagonal, located almost directly below raR, and obliquely at right below rpB′. Length of pB,

8.5 mm., width 7.5 mm.; measurements of other BB (except rpB and rpB′) approximately the same.

RR 5, pentagonal, except raR which is hexagonal, laterally in contact except at posterior interradius, where lpR adjoins anal x and rpR is next to rt. Articular facets straight or very gently concave upward, equal to maximum width of RR. Length, 6.0 to 6.5 mm., width of anterior RR, 11.0 to 12.0 mm., posterior RR, 9.0 to 10.0 mm.

Three anal plates are definitely identifiable in the dorsal cup. The plate, which on account of its position obliquely above pB and beneath rpR, is interpreted as RA, touches rpB′ at the right below, and along its upper left margins is in contact with anal x and rt. Because of the short length of the suture beneath rt, the shape of RA, although actually pentagonal, is nearly quadrangular. It is 5.5 mm. in longer dimension and 4.0 mm. at right angles to this. Anal x is about twice as long as wide; it is narrowly in contact with pB below, and touches laterally RA, rt, lpR and IBr of the left posterior ray. A tube plate that rests on x and rt is visible. The remaining plate in this part of the anal series, rt, is also longer than wide; it is pentagonal in outline, its base touching RA. About one-third of the height of x and rt is above the upper margin of the RR.

Primibrachs in each of the five rays are large axillary plates of approximately equal size, maximum length about 7.5 mm.; summit moderately elevated but surface of plates otherwise smoothly rounded; laterally in contact except at posterior interradius where a tube plate that lies above x and rt intervenes. Secundibrachs quadrangular, all except lowermost being distinctly wider than long; closely in contact all around. The arm segments are quadrangular in cross section, the outer face being nearly plain, the lateral faces also plain where the arms adjoin, and the inner face depressed in the middle by a moderately narrow ambulacral groove. Pinnules in lower part of arms apparently absent. So far as known there are 10 equal, uniserial arms.

The surface of all of the plates, both of the calyx and of the arms, is ornamented by a very distinct but delicate pattern of inosculating ridges. This pattern may be compared to skin

whorls except for much greater intricacy of design. The marginal portions of each plate, about 0.5 mm. in width, are smooth. The sutures between the plates are finely denticulate.

The broken top of the specimen shows clearly the cross section of an anal sac, about 7.0 mm. in diameter. It is centrally located within the ring of arms and is nearly circular in section. The walls of the sac are formed of thin plates which bear short projections on the interior side. There appear to be about 10 plates around the sac at the height of the fractured surface.

Remarks.—This beautifully ornamented and distinctive crinoid is closely similar to no other known Pennsylvanian species. In outline it resembles *"Poteriocrinus" macoupinensis* (Worthen), from lower Pennsylvanian beds of Illinois, but this latter species is distinctly smaller, unornamented, and lacks the additional plate obliquely below RA at right. The arms of the Illinois species are unknown.

The species is named for Prof. C. L. Foster of Bacone College, Muskogee, Okla., who found the specimen on which description has been based.

Occurrence.—Brentwood limestone, Morrow subseries, Pennsylvanian (Upper Carboniferous); Loc. 4519, Keough quarry, sec. 36, T. 16 N., R. 19 E., about 2 miles north of Fort Gibson, Okla.

Type.—Holotype, Kansas Univ., no. 45194.

Genus SCYTALOCRINUS Wachsmuth and Springer, 1879

This genus has a slender crown, conical cup with 3 anal plates at the posterior side, and 10 uniserial arms, branching on the first or second IBr; stem round. A dozen or more species of Lower Carboniferous age have been described, but as yet none from Pennsylvanian strata.

Scytalocrinus sansabensis Moore and Plummer, n. sp.

Plate XIV, figures 9a, b; text-figure 9

Calyx rather steeply conical; width at summit of RR, 6.7 mm. in holotype, 5.8 mm. in paratype; height, 5.5 mm. in holotype, 4.8 mm. in paratype.

IBB 5, quadrangular, all but small proximal portion covered by stem, about 0.9 mm. in diameter, distal part forming steep-sided cone; height about 1.6 mm.

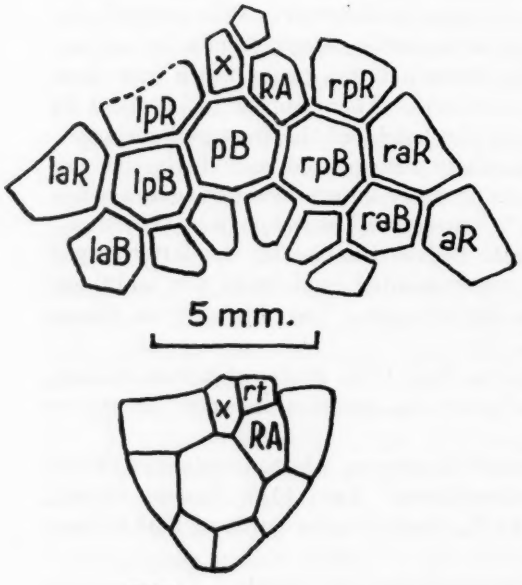


Fig. 9

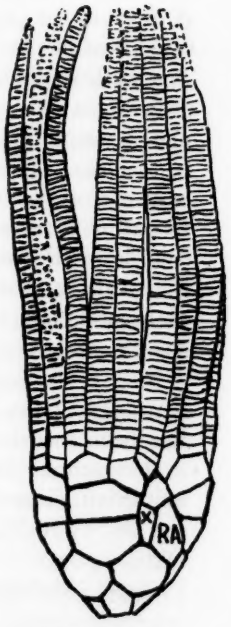


Fig. 10

FIGS. 9 AND 10. TWO MORROW POTERIOCRINIDS WITH CONICAL CUPS SHOWING INFRABASALS VISIBLE FROM SIDE

(*9*), *Scytalocrinus sansabensis*, n. sp., diagram of plates in dorsal cup, and posterior view of cup; Marble Falls limestone. (*10*), *Ulrichicrinus oklahomae* Springer, posterior view of crown (after Springer); Morrow, northeastern Oklahoma; ×1.

BB 5, hexagonal, except pB and rpB which are heptagonal, width about equal to length.

RR 5, pentagonal, length about two-thirds of width, upper margins straight, sides sloping uniformly but slightly more ver-

tical than BB. Articular facets, as shown on two RR of paratype, nearly at right angles to plane of outer face, divided by distinct transverse ridge into outer ligament area, about 0.6 mm. in width, and inner ligament and muscular area, 0.8 mm. or slightly more in width; a narrow, deep ligament pit, about 0.9 mm. long, closely adjoins the transverse ridge externally.

Anal plates 3; RA is hexagonal, resting on pB and rpB, adjoining anal x at left, and supporting rpR and rt; anal x rests on the truncated tip of pB and is broadly in contact with lpR; rt rests in the angle between anal x and RA, slightly touching rpR on its right. Anal x and rt project very slightly above the line of the RR; succeeding tube plates not observed.

Arms apparently 10, a dichotomous branching being observed following each IBr_1 which is axillary and about twice as long as wide; arms uniserial, segments slightly cuneiform, bearing pinnules; height of crown, 25 to 30 mm.

Stem round, 0.9 mm. in diameter, composed of alternating slightly thinner and thicker segments with rounded edges. No sac observed.

Remarks.—The generic assignment of *S. sansabensis* has been made with some hesitation, mainly because the shape of the calyx is a little more steeply conical than in the genotype and because the arm segments are slightly longer than is common in this genus. Essential structural similarities, however, support the conclusion that it belongs better here than elsewhere.

Among described species, *S. sansabensis* resembles closely only *"Poteriocrinus" macoupinensis* Worthen, from the Pennsylvanian—probably lower Missouri subseries—of Illinois. The latter form, the type of which is in hand for comparison, agrees with our species in shape and in structure of the dorsal cup but the Illinois form is more than twice as large. Only the dorsal cup of *"P". macoupinensis* is known; possibly it belongs to *Scytalocrinus*, but in spite of similarity of shape to the specimens here described from Texas, almost certainly it represents a different species.

The form of calyx of this species, structure of the anal area and plan of the arms suggests comparison with *Hydriocrinus*. The Texas form differs in not having the anal plates of the cup marked

off by a line even with the summit of the RR, in showing no indication of secondary branching on about the 14th IIBr, and in having a round rather than a pentagonal stem. *Dicromyocrinus* Jaekel differs in the globular shape of the cup.

Occurrence.—Marble Falls limestone, upper middle part, on Rough Creek, San Saba County, about 15 miles southeast of the town of San Saba, Texas (Loc. 151–M–1 in Plummer and Moore, Texas Univ. Bull. 2123, 1921).

Types.—Syntypes, Univ. Chicago Walker Museum no. 31721; collected by R. C. Moore.

Genus ULRICHICRINUS Springer, 1926

This genus is intermediate in characters between *Pachylocrinus* Wachsmuth and Springer, *Scytalocrinus* Wachsmuth and Springer, and *Woodocrinus* De Koninck. It is distinguished chiefly by the structure of the arms, which are slender, uniserial, with cuneiform segments, and 3 or 4 to the ray, branching on IBr_1 and $IIBr_1$.

Ulrichicrinus oklahomae Springer

Text-figure 10

Ulrichicrinus oklahomae SPRINGER, 1926, U. S. Nat. Museum, Proc., vol. 67, art. 9, p. 76, pl. 20, figs. 1, 2.

The only known species belonging to this genus in Morrow beds is *U. oklahomae* Springer, the genotype, from the vicinity of Crittenden, Okla. No specimen referable to this species has been collected by us, but it is illustrated here (Text-fig. 10).

Genus AGASSIZOCRINUS Owen and Shumard, 1852

This genus is characterized by the elongate form of its cup, which is rounded or pointed below and characterized especially by relative prominence and massive character of the IBB circlet. Very commonly the IBB are fused to form a single conical or semi-elliptical mass that is radially scalloped at the top in five divisions. Such fused IBB circlets are rather generally found separated from remaining parts of the calyx and in some cases

they are the only recognized traces of occurrence of the genus. The smooth base of the *Agassizocrinus* cup, lacking a stem impression, as shown by the fused IBB, indicates a stemless, free-swimming condition, but Springer (1926, pp. 53–64, pl. 15) has shown that some species belonging to this genus possessed a stem, and varying degrees of completeness of fusion of the IBB also appear. Complete specimens of the dorsal cup show that the two antero-lateral RR are typically larger than the others, and indicate the presence of three anal plates below the summit of the RR.

Genotype, *Agassizocrinus conicus* Owen and Shumard

Remarks.—Of 17 described species of *Agassizocrinus* all but one, *A. carbonarius* Worthen, are reported from Mississippian (Chester) rocks, and from this it may be concluded that the genus is essentially characteristic of late Lower Carboniferous time. Discovery of fairly numerous specimens belonging to *Agassizocrinus* at various places and at several horizons in the Pennsylvanian rocks of Arkansas, Oklahoma, Kansas and Texas calls for modification of the assigned range and distribution of the genus, but the fact remains that it is best developed in the Chester formations. Two species are here reported from Morrow beds of northeastern Oklahoma and northwestern Arkansas.

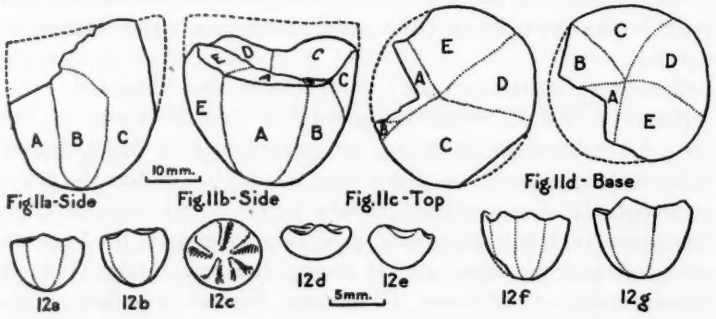
Occurrence.—Upper Mississippian, lower and middle Pennsylvanian, North America.

Agassizocrinus magnus Moore and Plummer, n. sp.

Plate XVI, figure 5; test-figure 11

Description of this species is based on two specimens of IBB fused circlets that are striking in their large size. The holotype, slightly elliptical in cross section, measures 23 mm. in longer diameter at the top and its height is 20 mm. Sides nearly vertical, base evenly rounded; top of the holotype, which is somewhat weathered, slopes inward to a central depression; plates entirely fused, no sutures being visible, but observation of crystal structure permits definite determination of the plate boundaries; base of paratype destroyed by weathering, but the top of the

specimen shows 5 rather strongly marked projections around the rim with radially disposed ridges sloping inward from these. As shown in accompanying drawings of the holotype, there is a curious asymmetry in development of the different infrabasal plates, some being distinctly narrower than others and one being obliquely truncated distally and overlapped by a thickening of its neighbor on the right.



FIGS. 11, 12. INFRABASAL CIRCLETS OF MORROW SPECIES OF *Agassizocrinus*

(*11*), *Agassizocrinus magnus*, n. sp., from the Kessler limestone near Morrow, Ark.; the dotted lines show position of edges of individual plates as determined from different orientation of crystalline calcite composing each plate, the plates being fused solidly so as to show no trace of sutures; the letters A-E are assigned arbitrarily to the five plates in order to permit identification of corresponding elements in the different drawings; *11a, b*, side views; *11c*, top view, the point of meeting of four plates being much lower than the rim; *11d*, basal view. (*12*), *Agassizocrinus caliculus*, n. sp., from the Brentwood limestone near Woolsey, Ark., and Fort Gibson, Okla.; *12a, b*, side views of holotype; *12c*, top view of holotype; *12d, e*, side views of a very low circlet; *12f, g*, side views of large specimens.

Remarks.—Springer (1926, p. 62) has expressed the opinion that species of *Agassizocrinus* that are described only on characters of IBB cones are not recognizable, even though no doubt exists as to generic assignment. All of the *Agassizocrinus* remains thus far collected from Pennsylvanian rocks consist only of fused IBB circlets. It is true that there are variations in these that probably have no specific value, but it also seems clear that forms in our collections from different horizons represent

different species. If these fossils have any stratigraphic value it is desirable to seek to recognize the different kinds.

A. magnus is separable from all other known Pennsylvanian species of this genus on the basis merely of its relatively huge size. Whether or not the unequal development of different IBB is a character of specific importance we cannot say definitely.

Occurrence.—Kessler limestone, Morrow subseries, Pennsylvanian (Upper Carboniferous); Loc. 4527, Hale Mountain, 0.5 mile south of Morrow, Ark.; collected by R. C. Moore.

Types.—Kansas Univ., holotype, no. 45271; paratype, 45271a.

Agassizocrinus caliculus Moore and Plummer, n. sp.

Plate XIV, figure 2; text-figure 12

A dozen or more specimens of IBB cones of dimutive size were collected from the Brentwood limestone near Fayetteville, Ark., and one specimen that is apparently identical with these, has been obtained from the Brentwood limestone north of Fort Gibson, Okla. Although there is variation in relative height, there is sufficient similarity in the flatly rounded base and appearance of the top of the cone to warrant the conclusion that they represent a single species. The specimen selected as holotype is of intermediate size, measuring 7 mm. in greatest diameter, and 5 mm. in height. Top marked by prominent radiating ridges, the crests of which rise gently inward, being terminated abruptly near the center where a small pit occurs; broken specimens show that the small central pit marks the opening of a narrow canal that extends partly or entirely to the base of the cone, in the latter case being associated with a small, shallow stem impression; traces of a stem are observed only in some of the smallest and apparently most immature examples, which also show definitely angular sutures for contact with BB and traces of inter-IBB sutures.

Remarks.—This species is smaller and much more evenly rounded at the base than in *A. carbonarius* Worthen, the types of which we have for comparison; the IBB cones of *A. carbonarius* are broadly and rather deeply hollowed so that the top does not

at all resemble that of *A. caliculus*. Because of the approximate uniformity in size of this small species there is little reason to consider the possibility that it is a juvenile stage of *A. magnus*.

Occurrence.—Brentwood limestone, Morrow subseries, Pennsylvanian (Upper Carboniferous); Loc. 4522, road cuts on U. S. Highway 71, opposite Woolsey, Ark., collected by R. C. Moore and F. B. Plummer; Loc. 4519, Keough quarry, about 2 miles north of Fort Gibson, Okla., collected by C. L. Foster.

Types.—Kansas Univ., holotype, no. 45228 (Loc. 4522), paratypes, nos. 45228a–f (Loc. 4522); paratype, no. 451915 (Loc. 4519).

SECTION II.—GENERA WITH SUBGLOBULAR CUPS CONTAINING TWO OR THREE ANAL PLATES

This group of crinoids is represented by six known species of Morrow species: *Cromyocrinus grandis* Mather; *Ethelocrinus oklahomesis* Moore and Plummer, n. sp.; *E. papulosus* Moore and Plummer, n. sp.; *E. hispidus* Moore and Plummer, n. sp.; *E. subsinuatus* Moore and Plummer, n. sp.; and *E. costalis* Moore and Plummer, n. sp.

Genus CROMYOCRINUS Trautschold, 1867

Much confusion has existed in characterization of Carboniferous genera of crinoids belonging to this and allied forms. *Eupachycrinus* Meek and Worthen, (1865), *Cadocrinus* Wanner (1924), *Ethelocrinus* Kirk (1937), and *Phanocrinus* Kirk (1937), may be distinguished from *Cromyocrinus* by the presence of a basal concavity and, in part, by different arm structure. *Ulocrinus* Miller and Gurley (1890), resembles *Cromyocrinus* in having a convex base, the IBB being clearly visible from the side, but in *Ulocrinus* there are only two anal plates in the cup. Jaekel (1918) has restricted application of *Cromyocrinus* to forms with the simple arm structure of the genotype, *C. simplex*, in which there are only 5 short, uniserial arms, and he has defined, under the name *Dicromyocrinus*, forms having 10 arms composed of cuneiform to biserially arranged segments.

Cromyocrinus grandis Mather

Text-figure 13

Cromyocrinus grandis Mather, 1915, Denison Univ. Sci. Lab., Bull., vol. 18, p. 102, pl. 3, figs. 2. 2a, text-fig. 1.

Mather collected a very large crinoid calyx of subglobular form having the structural characters described under *Cromyocrinus*. This specimen, from the Brentwood limestone near Brentwood, Ark., represents a species that is distinguished by its size, the projection for attachment of the stem, close union of the IBB, and the constriction of the upper part of the RR. A specimen

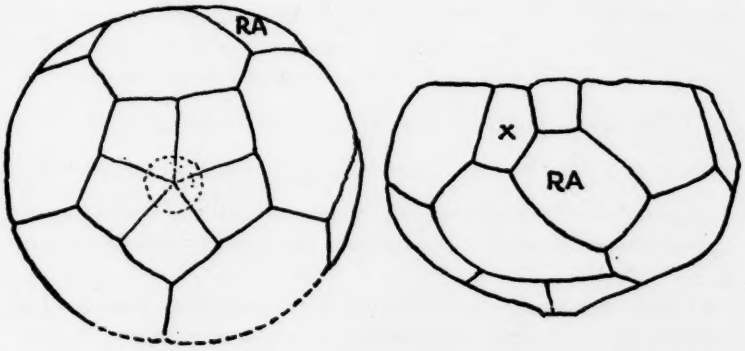


FIG. 13. *Cromyocrinus grandis* MATHER, BASAL AND POSTERIOR VIEWS OF DORSAL CUP (AFTER MATHER)

collected from Morrow beds on Braggs Mountain southeast of Fort Gibson, Okla., probably belongs to this species, but it is too poorly preserved for positive identification.

Whether this Morrow crinoid belongs to *Cromyocrinus* or to *Dicromyocrinus* is not definitely determinable, since the character of the arms in *C. grandis* is unknown. We are disposed to agree with Jaekel in separation of these genera.

Genus ETHELOCRINUS Kirk, 1937

Kirk (1937) has recently shown that all of the Pennsylvanian species that commonly have been identified as belonging to the

genus *Eupachycrinus* differ from the genotype species in having only two instead of three anal plates within the dorsal cup. He has introduced the new genus *Ethelocrinus* to include forms of *Eupachycrinus* type having only RA and anal x, of the anal series, in the dorsal cup; the genotype is *Eupachycrinus magister* Miller and Gurley.

Ethelocrinus is distinguished from *Cromyocrinus* and *Dicromyocrinus*, as from *Eupachycrinus*, by the presence of only two anal plates in the dorsal cup, from *Ulocrinus* by presence of a basal concavity. *Cadocrinus* Wanner (1924), from the Permian of Timor, has a calyx form and, in some examples, an anal plate arrangement in the cup like that of *Ethelocrinus*, but this Permian genus is distinguished by clearly marked differences in the nature of the articular facets, in possession of a mushroom-like anal sac, and in the generally smooth surface of the plates.

Ethelocrinus oklahomensis Moore and Plummer, n. sp.

Plate XIII, figures 1a-e; plate XV, figures 3a-h; text-figure 14

This handsomely decorated, medium-sized species is represented in our material by two calices and by very numerous separated plates.

Calyx a flattened bowl with nearly vertical sides, rounded below and above, the greatest diameter at about mid-height, 28 mm. in holotype, 32 mm. in paratype; height about one-half of width, measuring 14 mm. in holotype and 15 mm. in paratype. Base of cup hollowed, the nearly flat, gently concave IBB disk being set sharply inward; depth of basal concavity, measured from stem impression to a plane on which the calyx might rest, 4 mm.

IBB 5, forming a regular pentagonal disk about 9.5 mm. in diameter; sutures faint; stem impression round, 3.5 mm. in diameter, slightly below surrounding area, marked by about 35 short radial crenellae and perforated centrally by a quinquepartite canal, the petal-like lobes of which are radial in position.

BB 5, nearly equal, pentagonal, except pB, which is hexagonal; proximal part forming slopes of basal concavity, distal part curving into a vertical plane and rising somewhat above mid-height

of the calyx; these plates are strongly convex longitudinally and moderately convex transversely.

RR. 5, pentagonal, about twice as wide as long, proximal and medial parts approximately vertical, distal part curving inward; longitudinal convexity only slight. Articular facets nearly plane and subhorizontal in position, their outer borders forming together a strongly marked pentagon with straight sides, the inner edges rounded to make a nearly circular opening to the body cavity, this opening having a diameter of 15 mm. in the holotype; external ligament fossa a narrow, clearly defined groove that is separated from the outer face of plate by a ridge comparable in strength to the transverse ridge which bounds its inner side, greatest width of fossa about 1.5 mm.; a fairly deep ligament pit, 4 mm. long occurs in the mid-part of the fossa; the transverse ridge has a nearly vertical outer slope and a gentle inner slope, being thus markedly asymmetrical in cross-section; interarticular ligament fossae appear as a pair of broad subtriangular faint depressions that are bounded on the side toward the interradial sutures by ridges, a narrow depressed area occurring between these ridges of adjacent facets; muscular fossae, consisting of shallow depressions near the inner margin of facet, are divided by a well marked but narrow intermuscular notch.

There are two anal plates in the dorsal cup, a relatively large, quadrangular RA and a much smaller anal x; RA lies between pB and rpB, below, and rpR and x, above; x is pentagonal in form, a very short suture at its contact with pB, longer ones at other sides; the proximal three-fifths of anal x slopes slightly inward from a vertical plane, the remaining two-fifths being inflected sharply to a nearly horizontal position that is only very little above the plane of the articular facets; an interesting but expectable feature is persistence of the distinctive tuberculated surface ornamentation on the bent part of x that lies between facets of the posterior RR.

Surface of calyx ornamented by two orders of tubercles, round, relatively even-spaced spines that project about 1 mm. or slightly more above the general level of the plate, and rounded or elongate small granules between the spines; a space on each plate

adjoining the sutures is nearly smooth and somewhat depressed, so that the position of all sutures, except those of the IBB circlet, is strongly marked.

Many separated BB and RR and one or two IBB disks, belonging to this species, have been collected. They can be identified very easily by noting approximate size, shape, and ornamentation. The interior of the plates is smooth. The fact that these plates may be found at almost any outcrop of the Brentwood limestone indicates that the species is fairly common, though good calices are seemingly rare.

Remarks.—*E. oklahomensis* is similar in size and shape to *E. verrucosus* (White and St. John) but differs in ornamentation and various other details. *E. tuberculatus* (Meek and Worthen) is characterized by coarse rounded tubercles that are arranged approximately as in our species but examination of authentic specimens of the Illinois species indicates an absence of fine granules as well as differences in the appearance of the large nodes; besides, *E. tuberculatus* is a much broader, flatter species. *E. oklahomensis* is not at all like the holotype of *E. magister* (Miller and Gurley) although it somewhat resembles specimens that have been identified by certain authors as belonging to this species. The cup of *E. magister* is broader, flatter and heavier; and the ornamentation is hardly to be confused with that described for this Morrow form.

Among associated species of *Ethelocrinus* that are recognized in Morrow beds, *E. costalis*, n. sp., most closely resembles the form here described; *E. oklahomensis* is distinguished by the somewhat larger size of the coarse, rounded tubercles, greater distinctness of fine granular ornamentation, and thicker plates that show no internal radiating corrugations. *E. hispidus*, n. sp., and *E. papulosus*, n. sp., have entirely different surface ornamentation, and *E. subsinuatus*, n. sp. has both a dissimilar appearance of the surface and a readily observed difference in shape of the radials.

No observed specimen of *E. oklahomensis* shows any part of the arms, but we have a beautifully preserved IBr (Pl. XVI, figs. 6a–e) that carries the ornamentation of this species and

probably belongs to it. This plate is low, rather sharply pointed, and carries a single large tubercle at its tip.

Occurrence.—Brentwood limestone, Morrow subseries, Pennsylvanian (Upper Carboniferous); Locs. 4519, 4520, Keough quarry, sec. 36, T. 16 N., R. 19 E., north of Fort Gibson, Okla., collected by C. L. Foster and R. C. Moore; Loc. 4521, Braggs Mountain, about 3 miles southeast of Fort Gibson, collected by R. C. Moore; Loc. 4522, road cut on U. S. Highway 71 opposite Woolsey, Ark., collected by R. C. Moore and F. B. Plummer; also several other localities.

Types.—Holotype, Univ. Oklahoma paleontological collection (specimen collected "north of Muskogee, Okla.", probably from Keough quarry, loaned by Dr. C. E. Decker); plastoholotype, Kansas Univ., no. 45281; paratype, calyx collected by R. Rose (Muskogee, Okla.); paratypes (separated plates), Kansas Univ., (radials) nos. 41914a-f; (basals) 41914g-k, (IBB disk) 419141.

Ethelocrinus papulosus Moore and Plummer, n. sp.

Plate XV, figures 5a-f; text-figure 15

This species is based on two large radial plates, one of which is designated as holotype, and a basal plate, which with the other radial are indicated as paratypes.

RR unusually large, measuring 25 mm. in width and 17 mm. in length in the plate classed as holotype; moderately convex. Outer face covered by closely spaced irregularly shaped small nodes which produce a rough appearance without definite pattern. Articular facets broad, 11 mm. in width, measured at midpoint from outer margin to line connecting inner lateral angles; outer (proximal) border marked by sharp edge of the rough ornamentation of the outer face, curving gently outward from upper angles of RR; transverse ridge prominent, straight, sharp-crested, finely denticulate, outer edge vertical, inner edge sloping steeply; external ligament fossa well defined, moderately excavated; ligament pit narrow, sharply marked; interarticular ligament fossae defined as concave sub-triangular areas on each side of the center, adjacent to the transverse ridge on distal side; muscular

fossae broad, weakly separated from interarticular ligament fossae; strongly marked depressions on each side of well defined intermuscular furrow; distal margins of articular facet turned sharply upward making facets distinctly concave as a whole. Inner surface of plate marked by radiating ribs of which three that meet the lower angles of the radial are most prominent, the rest being oriented at right angles to the marginal sutures; no definite pore structure is evident in connection with these ribs; there are about 13 of the fainter ribs that intersect the proximal inner margin of the plate on each side between the point and the lateral inferior angles. Radials have a thickness of about 3 mm. along the proximal and most of lateral margins. Sutures are at right angles to outer face, ribbed or plane, except for fine crenulations arranged in groups, each of which has a pattern somewhat resembling a fern pinnule. BB about 21 mm. in length and 25 mm. in maximum width, gently and regularly convex; paratype which is a lpB, laB or raB is hexagonal, the two short proximal margins lying nearly in a straight line. The external and internal markings, thickness of plate and characters of the suture correspond wholly with those of the described R and there is little doubt that both belong to a single species.

Reconstruction of the upper part of the cup based on R and B indicate a large cup of sub-hemispherical outline, about 23 mm. in height and 46 mm. in maximum width, at about the mid-height of the RR.

Remarks.—The distinctive features of the plates of *E. papulosus* are their size, thickness, and external and internal markings which make indentification easy.

E. hispidus Moore and Plummer has similar external markings but is smaller, is smooth inside, and has distinctly different features of the articular facets.

Occurrence.—Brentwood limestone, Morrow subseries, Pennsylvanian (Upper Carboniferous); Loc. 4519, Keough quarry, Sec. 36, T. 16 N., R. 19 E., Okla.

Types.—Kansas Univ., holotype, no. 45198; paratypes, 45198 *a, b;* collected by C. L. Foster, Bacone College, Muskogee, Okla.

Ethelocrinus costalis Moore and Plummer, n. sp.

Plate XV, figures 2a-h; text-figure 16

Eupachycrinus cf. *magister* Miller and Gurley, MATHER, 1915, Denison Univ. Sci. Lab., Bull., vol. 18, p. 104, pl. 2, fig. 8, ?7, ?9

Nearly five dozen plates, about one-fourth of them RR, the others being BB, are distinguished from the other very numerous *Ethelocrinus* plates by their comparative thinness, strongly corrugated interior surfaces, coarsely tuberculate exteriors and narrowness of sutural faces. These evidently belong to a species that is common in the Morrow beds but perhaps because of the apparent looseness of union between plates of the calyx has not thus far been observed as a complete specimen. Reconstruction based on the joining together of like-sized plates indicates a somewhat high sub-globose cup about 16 mm. high by 27 mm. in maximum width.

RR about twice as wide as long, measuring typically about 17 mm. wide by 9 mm. long, outer face gently and rather evenly convex, covered by some 12 to 18 coarse rounded tubercles, each about 1 mm. in diameter and in height, the comparatively smooth areas between these tubercles marked by more or less abundant minute tubercles or granules. Articular facet forming an obtuse angle of about 120° with outer face of plate; external ligament area approximately equal in width to inner area which is much narrower than in the case of associated species; transverse ridge very narrow, straight, but median portion depressed with respect to lateral parts; external ligament fossa and pit narrow; interarticular ligament fossae on inner side of transverse ridge obscure, hardly differentiated from the narrow triangular muscle areas; inter-muscular notch very broad, its inner point reaching almost to the transverse ridge. Inner surface of RR marked by three especially prominent ridges which diverge from a point near base of inter-muscular notch and join the lower angles of the plate. Between these are very distinct but smaller ridges normal to the plate margins, about eight of these lesser ridges occurring between each two of the main ridges and three or four between the lateral

main ridges and the upper angles of the plate; except for these ridges and a general concavity between the main corrugations the interior surface from the border of the articular facet to the proximal margin of the plate is nearly plane.

BB show external and internal features entirely similar to those of the RR but these plates are relatively more convex; the main ridges on the interior diverge from a point near the center to each of the five main angles; in some cases faint cross markings parallel to the plate margins are observed both in BB and RR, producing a somewhat cancellated appearance. A plate of average size is 17 mm. wide and 15 mm. long.

Remarks.—The external ornamentation of *E. costalis* is very similar to that of *E. oklahomensis* but the large tubercles of the latter are typically more elevated, somewhat more widely spaced and the fine granular ornamentation is much more distinct; the articular facets of *E. oklahomensis* are relatively broad, the plates are thick, with broad flat suture surfaces, and the interior of the plates is smooth. The internal corrugations are relatively stronger than in *E. papulosus* and the external ornamentation is much coarser than in this species; *E. costalis* is also evidently a distinctly smaller form.

Mather (1915, pl. 2, fig. 8) has figured under the designation, *Eupachycrinus* cf. *magister* Miller and Gurley a radial plate that can be distinguished as belonging to *E. costalis*. Whether or not the external views of two additional plates as given by him belong to the same species cannot be determined definitely. There is certainty, however, in the conclusion that these plates do not belong to *E. magister*.

Occurrence.—Brentwood limestone, Morrow subseries, Pennsylvanian (Upper Carboniferous); Keough quarry, sec. 36, T. 16 N., R. 19 E., and Braggs Mountain about 3 miles southeast of Fort Gibson, Oklahoma, and near Woolsey, Arkansas.

Types.—Kansas Univ. Type Collection, holotype (B) no. 451912; paratypes (BB) no. 451912*a-z*, *a'-e'*, 45225*a-i*, (RR) no. 451912*f'-k'*, 45225*j-m*. Collected by C. L. Foster and R. C. Moore.

Ethelocrinus hispidus Moore and Plummer, n. sp.

Plate XV, figures 4a-g; text-figure 17

Recognition of this species is based on study of a considerable number of separated plates from which an especially well preserved rpR is selected as holotype representative of the species and four other RR and three BB are selected as paratypes. Reconstruction of the dorsal cup based on this material indicates a calyx that is about half as high as wide, estimated height being about 19 mm. and maximum width about 37 mm.

IBB circlet not observed.

BB gently and rather evenly convex, mostly hexagonal, the two proximal sutures adjoining IBB forming together a nearly straight line; length of inter-BB sutures a little shorter than B-R sutures. Length of typical example, a paratype 23 mm., width 23 mm. Outer surface covered by numerous irregularly disposed rather small tubercles; toward margins of plates in several examples, but apparently not all, tubercles coalesce to form narrow discontinous ridges that trend at right angles to plate margins. Interior entirely smooth. Sutures marked by numerous fine denticles arranged in groups or bundles so as to form more or less distinct but low ridges trending at right angles to suture edge. Plates moderately thick, averaging 2.5 to 3 mm. at sutures and somewhat more in central part of plate.

RR pentagonal, length slightly more than half of width, moderately convex, and judging by slope to plate margins, slightly bulbous; external surface marked as in BB; inner surface smooth; sutures marked by well defined ridges and shallow grooves, the former bearing irregularly placed fine ridglets. Articular facets broad, 10 mm. in holotype, which is an unusually well preserved example; external ligament area differentiated from outer face by distinct angulation and by absence of tubercles, contains on inner half moderately narrow fossa that is clearly defined to lateral margins and inside of this, marked off by a low ridge, a fairly deep ligament pit. Transverse ridge straight, prominent, and bearing along crest numerous fine pits and denticles. In-

ternal ligament area contains narrow inter-articular ligament fossae that curve slightly inward from lateral margins and extend nearly to the inter-muscular furrow; muscular fossae developed on sloping sub-triangular areas on either side of the deep inter-muscular notch and each bearing three rather strongly impressed grooves that converge toward the transverse ridge; the bottoms of these furrows are marked by curving cross lines; the pitted area next to transverse ridge at base of inter-muscular furrow probably marks position of central canal.

Remarks.—This species is distinguished by the size and shape of plates, external ornamentation, smooth interior and by characters of the radial facets. The ornamentation is similar to that of *E. papulosus* but strongly marked ridges of the interior and different appearance of facets in this species permit ready separation.

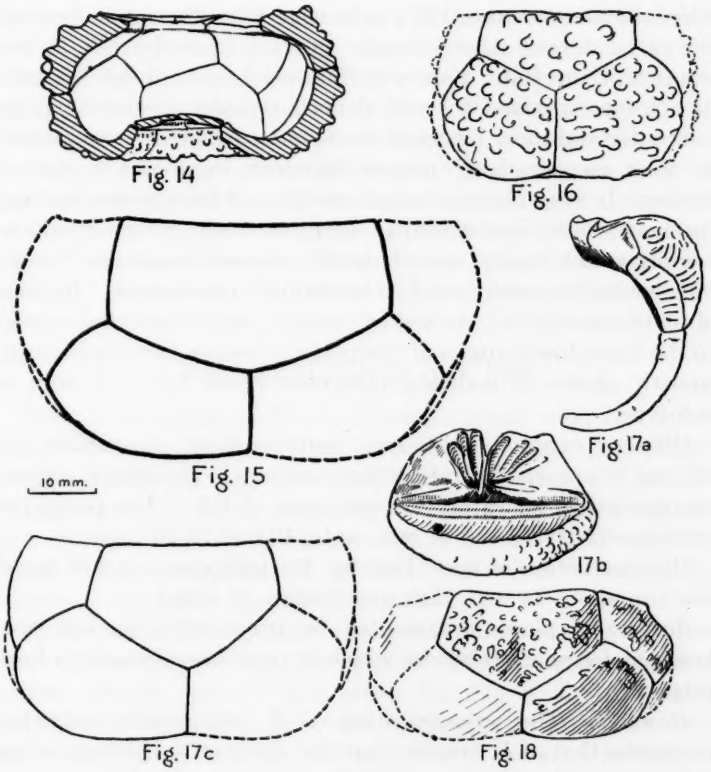
Occurrence.—Brentwood limestone, Morrow subseries, Pennsylvanian (Upper Carboniferous); Loc. 4519, Keough quarry, sec. 36, T. 16 N., R. 19 E., Okla.

Types.—Kansas Univ., holotype, no. 45199; paratypes 45199a-g; collected by C. L. Foster.

Ethelocrinus subsinuatus Moore and Plummer, n. sp.

Plate XV, figures 1a-g; text-figure 18

Description of this species is based on seven RR, one of which is selected as holotype, and two BB, these additional plates being classed as paratypes. The RR are readily distinguished from the large number of associated *Ethelocrinus* plates by the character of their surface ornamentation but especially by the median depression that extends longitudinally from the proximal tip. Viewed from below, these plates have a distinctly sinuous appearance that has been observed in no other Morrow representatives of this genus. Width of RR nearly twice the length; the holotype which is an average size specimen, is 17 mm. wide and 9.5 mm. long; the largest paratype is 20 mm. wide, 12.5 mm. long. Articular facets form an obtuse angle with the outer face



FIGS. 14–18. MORROW SPECIES OF *Ethelocrinus*

(*14*), Antero-posterior section through dorsal cup of *Ethelocrinus oklahomensis*, n. sp., showing basal concavity and position of various plates; a carefully constructed drawing based on study of the holotype. (*15*), Outline of dorsal cup of *Ethelocrinus papulosus*, n. sp., constructed from separated radial and basal plates. (*16*), Reconstruction of the dorsal cup of *Ethelocrinus costalis*, n. sp., based on study of separated plates. (*17*), *Ethelocrinus hispidus*, n. sp.; *17a*, profile view of right posterior radial and an underlying basal, showing suture ridges; *17b*, articular facet of right posterior radial, holotype, showing strongly marked external and internal ligament areas, the latter with paired sets of muscle furrows adjacent to intermuscular notch; *17c*, outline of dorsal cup based on study of separated plates. (*18*), Restoration of dorsal cup of *Ethelocrinus subsinuatus*, n. sp., based on study of separated plates.

which measures about 125°, indicating that the upper part of the calyx slopes rather strongly outward from the line of the summit of the RR. Facets moderately broad, about 7.5 mm. in holotype, divided by well defined straight transverse ridge into outer and inner ligament areas; outer ligament area marked by long comparatively narrow ligament fossa and a shorter moderately deep ligament pit; inner part of facet shows in some specimens faint inter-articular ligament fossae near lateral extremities and nearly smooth gently concave muscular fossae, inter-muscular notch broad to moderately constricted. Interior of plates smooth but marked by distinct angulations that extend to the three lower angles of the plates. Suture faces apparently smooth; plates of moderate thickness, about 1.5 to 2 mm. in holotype.

BB show external and internal features closely resembling the RR but are nearly flat rather than concave in the central region; margins fitting curvature of lower faces of RR. The paratypes are respectively 15 and 17 mm. wide, 13 and 15 mm. long.

Reconstruction of cup (Text-fig. 18) indicates a rather broad low cup about 14 mm. high and 30 mm. in width.

Surface of plates ornamented by irregularly disposed very low rounded small tubercles which in part are coalesced to form ridges.

Remarks.—The ornamentation of *E. subsinuatus* somewhat resembles that of *E. hispidus* but the shape of the plates is quite different. Other species of *Ethelocrinus* from the Morrow beds have very much stronger more wide-spaced and well-rounded tubercles.

Occurrence.—Brentwood limestone, Morrow subseries, Pennsylvanian (Upper Carboniferous); Loc. 4519, Keough quarry, sec. 36, T. 16 N., R. 19 E., Okla.

Types.—Kansas Univ., holotype, no. 451911; paratypes, nos. 451911*a-h*; collected by C. L. Foster.

SECTION III.—GENERA WITH DEPRESSED BASIN-LIKE CUPS CONTAINING THREE ANAL PLATES

Pennsylvanian crinoids of the type indicated in this group have commonly been referred to the genus *Hydreionocrinus*. It

appears from study of the characters of the genotype of *Hydreionocrinus* that such procedure is unwarranted. Recognized in the Morrow fauna is one species of *Zeacrinus*, two species of a new genus, *Perimestocrinus*, and one each of the new genera *Plaxocrinus* and *Utharocrinus*. All of these are considered as allied to *Hydreionocrinus*, but the latter genus is not known to occur in Carboniferous rocks of North America. In addition to genera of this group that are represented in the Morrow beds, the two new Carboniferous genera *Sciadiocrinus* and *Xystocrinus*, including forms previously referred to *Hydreionocrinus*, are defined.

Genus ZEACRINUS Hall, 1858

One of the group of Carboniferous crinoids with low bowl-shaped or saucer-like dorsal cup having 3 anal plates at the posterior side is *Zeacrinus*. Much confusion has prevailed in generic differentiation of forms belonging to this group and there are various questions of classification that remain to be solved. Some of these problems will be considered in the following discussion of the genus *Hydreionocrinus*.

Species assignable to *Zeacrinus* include forms with a very low saucer-shaped dorsal cup, the base of which is commonly more or less strongly concave with rather flat closely abutting arms that branch repeatedly, but only on the inner side of the two outer branches of each ray, the segments of the arms being uniserial in arrangement, short, wide, and quadrangular (with occasional exception of cuneiform segments in the lower arm); the anal sac is a well developed, club-shaped or pyramidal structure that generally does not rise above the summit of the arms and that shows no overhanging mushroom-like distal expansion such as that of *Hydreionocrinus*. Springer (1926, p. 77) has recently discussed the generic characteristics of *Zeacrinus* and related forms, pointing out the features that seem to him chiefly significant, and has furnished good illustrations of the genotype, *Z. magnoliaeformis* Hall. Attention is especially called by Springer to the nature of the arms, and it is this rather than the form of calyx and structure of the anal sac, that is deemed by him to have greatest diagnostic value. Except to express doubt as to

Springer's inclusion in this genus of a lower Mississippian form (*Z. bursaeformis* White) with high conical cup, IBB clearly visible from the side,—a matter that does not especially concern us here—the diagnosis of *Zeacrinus* seems to be satisfactorily definite and clear. Concerning the calyx it may be noted that, despite considerable variation in the relative size and shape of BB, and relations of plates belonging to the anal interradius, there is a readily apprehended similarity in appearance of different species of *Zeacrinus*. Characteristic features of the dorsal cup are its shape, the close lateral junction and even summit level of articular facets of the radials, only moderate outward inclination of the facets, and the strong upward protuberance of thick plates belonging to the anal series.

Zeacrinus girtyi Springer

Text-figure 19

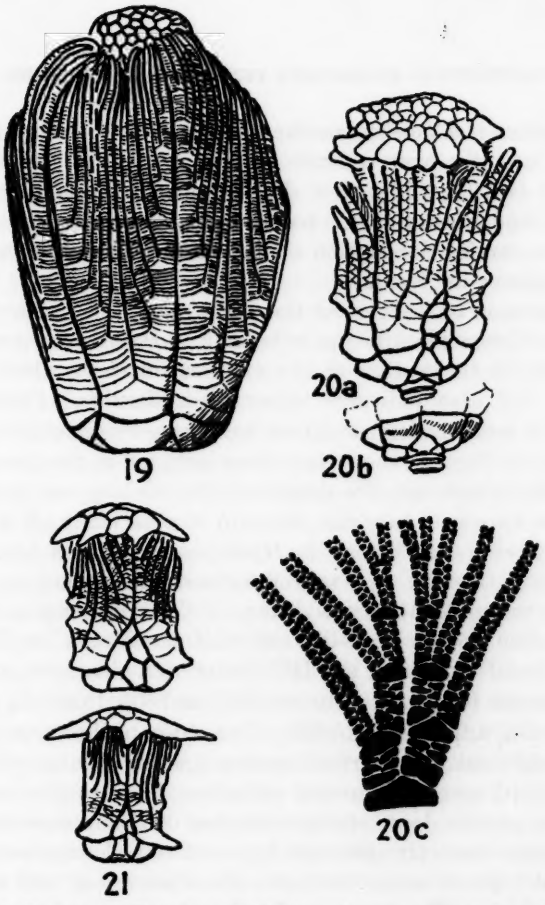
Zeacrinus girtyi SPRINGER, 1926, U. S. Nat. Museum, Proc., vol. 67, art. 9, p. 84, pl. 23, figs. 9, 9a.

A single species of *Zeacrinus*, called *Z. girtyi*, has been collected from beds of Morrow age. The holotype and only known specimen were found near Crittenden, in northeastern Oklahoma. No additional material has been obtained by us, and so a copy of one of Springer's figures is given here in order to illustrate all known types of Morrow crinoids. This species shows well the distinctive type of arm structure that has been noted in *Zeacrinus*. The rounded top of the anal sac rises slightly above the summit of the arms in this species.

Genus HYDREIONOCRINUS de Koninck, 1858

Text-figure 20

A tabulation of described crinoids from Upper Carboniferous rocks of North America shows that a larger number of species are currently assigned to this genus than to any other. Although not rightly understood by de Koninck, a character of *Hydreionocrinus* that has come to be regarded as the chief diagnostic feature



FIGS. 19–21. CROWNS OF *Zeacrinus*, *Hydreionocrinus* AND *Xystocrinus*, SHOWING CHARACTER OF ARM STRUCTURE AND ANAL SAC

(*19*), Anterior view of a remarkably preserved crown of *Zeacrinus girtyi* Springer, from the Morrow beds of northeastern Oklahoma (after Springer), showing very clearly the characteristic type of arm branching and very low dorsal cup of *Zeacrinus*; the anal sac, rounded at the top, projects somewhat higher than in most species of the genus but it lacks the mushroom-like terminal expansion that is seen in hydreionocrinids. (*20*), The genotype of *Hydreionocrinus*, *H. woodianus* De Koninck, showing low conical cup with infrabasals visible from side, branching biserial arms, and mushroom-like sac with ring of spines; *20a, b*, drawings of the holotype of *H. woodianus* (after Bather); *20c*, diagram to show arm structure of the genotype of *Hydreionocrinus* (modified from Bather) which is clearly unlike that of American hydreionocrinid genera here discussed. (*21*), Posterior views of two crowns of the genotype of *Xystocrinus*, n. gen., *X. depressus* (Hall), showing plan of arm branching as in *Zeacrinus* and strong mushroom-like sac as in *Hydreionocrinus* (after Springer). All figures, ×1.

of the genus is a mushroom-like anal sac, the top of which may project laterally over summits of the arms. Wachsmuth and Springer (1879, p. 131) first showed clearly the true nature of this sac, and Bather (1911) has added to knowledge by publication of a careful description of the characters of the genotype, *H. woodianus* de Koninck.

Comparison of features of the genotype species with those of American forms identified as belonging to *Hydreionocrinus* shows similarity in the nature of the anal sac in cases where this is known, but also indicates many dissimilarities. Despite the fact that generic determination has been based essentially on structure of the sac, there have been included in the genus many species for which only the dorsal cup, or the cup and part of the arms are known. As a rule, the cup of practically all American species assumed to belong in *Hydreionocrinus* is a low saucer-like disk with more or less well-defined basal concavity. This actually resembles the typical form of *Zeacrinus* cup much more closely than the low bowl-like cup of *H. woodianus*, for the latter lacks a basal concavity, the IBB being seen clearly in side view. In American forms not only are IBB invisible from the side but in some this applies also to BB. Our study of the range of structures exhibited by described species and by a large number of undescribed specimens in our collection, leads to the conclusion that the present loose characterization of *Hydreionocrinus* so as to include distinctly different types of dorsal cups and widely different types of arm structures, also, does not accord with true relationships. The presence of a distally expanded sac may well appear in generically distinct groups of crinoids. For example, Wanner (1924, p. 250) has defined the Permian genus *Cadocrinus* with *Hydreionocrinus*-like sac but with form of cup and nature of articular facets strongly in contrast to these in true *Hydreionocrinus*.

We propose to restrict definition of *Hydreionocrinus* to forms that agree substantially with the genotype in form of cup and structure of arms, as well as in the nature of the anal sac. Characters of the dorsal cup of *H. woodianus*, the genotype, have already been noted. The arms are biserial, several branches

appear in each ray, and, as emphasized by Bather, there is a distinctive type of branching, since only the inner two arms of each ray show bifurcations (see text-fig. 20). This plan of branching is very readily discriminated from that which is characteristic of *Zeacrinus*. Here, it is the two outer arms of each ray that give off branches, all of the inner arms being unbranched. If *Hydreionocrinus* is restricted to species that correspond to the genotype in structure of arms and shape of dorsal cup, it appears that no known crinoid from the Carboniferous rocks of North America is referable to this genus.

Awaiting future characterization of certain new types of post-Morrow crinoids belonging to this group, we may here indicate as distinct genera: (a) under the name *Xystocrinus* (from ξυστος covered colonnade) species formerly referred to *Hydreionocrinus* having strongly cuneiform to biserial arms that branch in the general manner of *Zeacrinus*, and for this genus *Zeacrinus depressus* Hall is taken as the type; and (b) under the name *Sciadiocrinus* (from σκιαδειον—umbrella) species formerly referred to *Hydreionocrinus* having rounded uniserial arms with quadrangular to slightly cuneiform segments, branching one or more times in essentially isotomous manner, and for this genus *Zeacrinus* (*Hydreionocrinus*) *acanthophorus* Meek and Worthen is taken as the type. There can be little doubt as to the validity of generic separation of these forms from each other and from true *Hydreionocrinus*. It is evident, however, that in the case of species that are now known only from characters of the dorsal cup a measure of doubt must exist as to proper generic allocation.

Genus XYSTOCRINUS Moore and Plummer, n. gen.

Text-figure 21

Hydreionocrinus (part), of authors.

Crown sub-cylindrical. Dorsal cup low basin-shaped; IBB 5, not visible from side, more or less covered by stem attachment and located in basal concavity of cup; BB 5, subequal; RR 5, with articular facets inclined somewhat outward; three anal plates

form part of dorsal cup, anal x and rt rising distinctly above summit of RR. Anal sac as in *Hydreionocrinus*. Arms strongly cuneiform to biserial, branching heterotomously from the two outer arms of each ray as in *Zeacrinus*, contour of arms somewhat rounded on outer side but tending to stand closely adjoining laterally; pinnules short. Stem round.

Genotype, *Zeacrinus depressus* Hall.

Remarks.—Described species of *Xystocrinus*, as here characterized, are all of upper Mississippian age, including, besides the genotype, *Hydreionocrinus wetherbyi* Wachsmuth and Springer, and possibly *Zeacrinus? armiger* Meek and Worthen and *Eupachycrinus? sanctiludovici* Worthen. *Zeacrinus mucrospinus* McChesney, which has been classed as a typical representative of *Hydreionocrinus*, occurring in lower or middle Pennsylvanian rocks, has arm structure referable to *Xystocrinus*. This species certainly does not belong to *Hydreionocrinus*, as restricted, and without evidence as to the nature of the tegmen, cannot be identified as belonging to *Xystocrinus*. The nature of the dorsal cup and the presence of spinose IBr do not agree with accepted examples of this new genus.

Occurrence.—Upper Mississippian (upper Lower Carboniferous), North America.

Xystocrinus? acicularis Moore and Plummer, n. sp.

Text-figure 22

Several small anal sac spines belonging to a hydreionocrinid resembling *X. depressus* are found in the Brentwood limestone. These plates are distinguished by the strong convergence of the lateral sutures, the relative sharpness of the spines and the nearly even thickness of the plate throughout. The vertical position of the lateral sutures indicates that there is very little outward down-tilting of the spines, but rather, they must have been carried nearly horizontal. A restoration of the summit of the anal sac, based on the average size and shape of plates in our collection, is given in text-figure 22.

Occurrence.—Brentwood limestone, Morrow subseries, Penn-

sylvanian (Upper Carboniferous); Loc. 4519, Keough quarry, north of Fort Gibson, Okla.

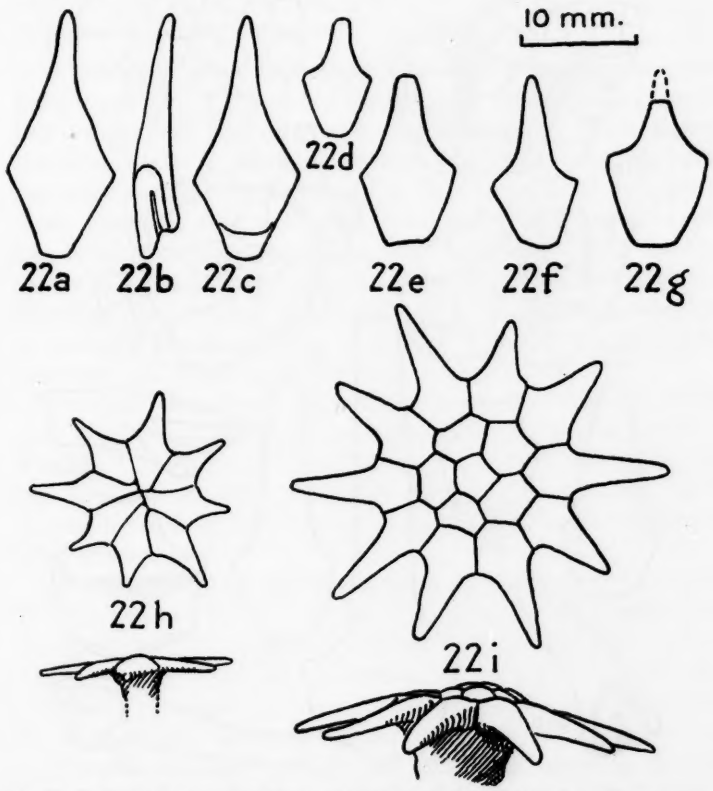
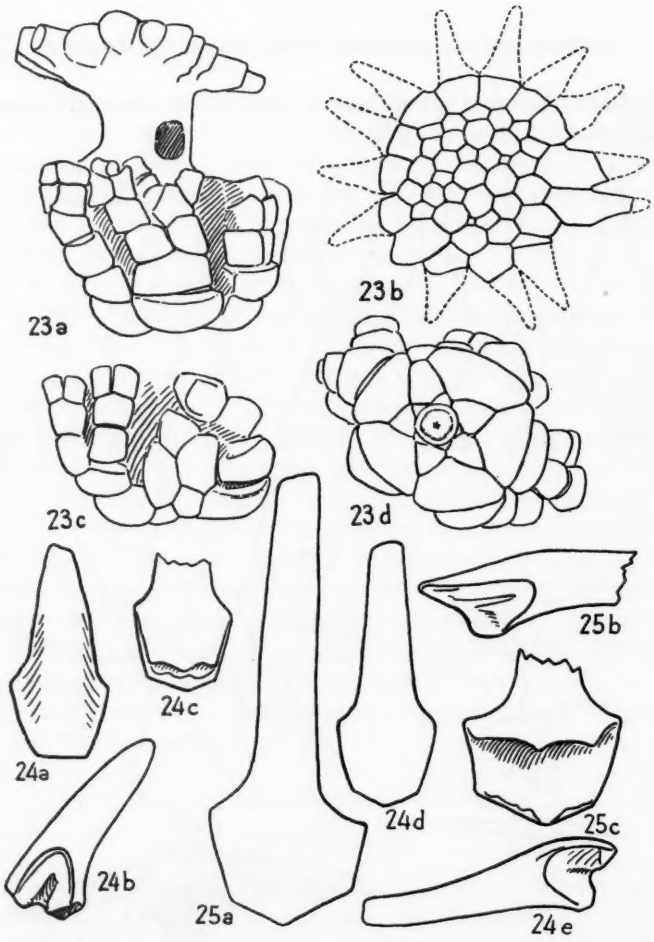


FIG. 22. ANAL SAC SPINES OF *Xystocrinus? acicularis*, N. SP. AND RESTORATION OF DISTAL PART OF SAC IN THIS SPECIES AND *Sciadiocrinus? crassacanthus*, N. SP.

22a–c, upper, side, and lower views of a typical spine of *X.? acicularis*, holotype specimen; *22d–g*, other specimens; *22h*, restoration of top of sac in *X.? acicularis*, somewhat doubtful; *22i*, restoration of top of sac in *S.? crassacanthus*, showing approximate arrangement of spines.

Types.—Kansas Univ., holotype, no. 451918; paratypes, nos. 451918*a-i*; both from Loc. 4519.



FIGS. 23–25. DRAWINGS OF *Sciadiocrinus acanthophorus*, GENOTYPE OF THIS NEW GENUS, AND SPINES OF SPECIES FROM MORROW BEDS

(*23*) *S. acanthophorus* (Meek and Worthen), accurate drawings of the holotype, from lower Pennsylvanian beds near Seaville, Fulton County, Ill.; ***23a***, view of crown from anterior side, showing arm structure, low cup, and typical hydreionocrinid anal sac (removal of matrix has shown position of anal opening at about mid-height of the sac on the anterior side); ***23b***, top of anal sac, showing girdle of spines, mostly broken in holotype; ***23c***, posterior view of crown; ***23d***, base of cup, the somewhat spraddled round arms appearing beyond the edge of radials. (*24*), Sac spines of *Sciadiocrinus? crassacanthus*, n. sp.; ***24a–c***, top, side, and bottom views of a typical spine, the holotype specimen; ***24d, e***, top and side views of a paratype. (*25*), *Sciadiocrinus?* sp., top, side, and bottom views of a large sac spine.

Genus SCIADIOCRINUS Moore and Plummer, n. gen.

Text-figure 23

Hydreionocrinus (part), of authors.

Crown short, somewhat expanded. Dorsal cup very low, with basal concavity; IBB 5, not visible from side; BB 5, generally not visible from side except at posterior; RR 5, facets slightly less than width of plates; anal plates 3, x and rt entering dorsal cup only slightly. Anal sac as in *Hydreionocrinus*, with prominent marginal spines at distal extremity, forming an eaves-like overhang; genotype shows rounded anal vent on anterior side of sac at about mid-height (shown by cleaning of Meek and Worthen's holotype). Arms rounded, isotomous, branching two or more times on each ray, segments uniserial, quadrangular, branches not laterally in contact. Stem round.

Genotype, *Zeacrinus* (*Hydreionocrinus*) *acanthophorus* Meek and Worthen. According to information supplied by Dr. H. R. Wanless, University of Illinois, the horizon from which this species was obtained is either the Seville limestone or the Oak Grove marine horizon of the Liverpool cyclothem, both of Cherokee (Des Moines) age.

Remarks.—Only the genotype species can be referred positively to *Sciadiocrinus*, for in no other form that has similar shape of dorsal cup and type of arms is there definite knowledge of the anal sac. The common occurrence in various Pennsylvanian horizons of spine-bearing plates of the distinctive type that forms the umbrella-like expansion at top of the sac in this genus indicates a considerable geologic and geographic range of crinoids having a mushroom-like, spine-bordered anal sac. Some of these spines are associated with dorsal cups like that of *Sciadiocrinus acanthophorus*, and accordingly it is reasonable to assign these cups to *Sciadiocrinus*, even though specimens showing sac and arms attached to cup are lacking. Dorsal cups of a pattern unlike that of the genotype, though possibly also joined originally with a *Hydreionocrinus*-like sac, should not be referred to *Sciadiocrinus*; it is preferable to define genera on the basis of characters of the dorsal cup, modifying classification as is necessary if and when complete crowns are discovered.

Defined on the basis of similarity of form of the dorsal cup to that of the genotype species, the following Pennsylvanian species may tentatively be assigned to place in this genus: *Zeacrinus mucrospinus* McChesney, *Z. mooresi* Whitfield, *Z.? robustus* Beede, *Hydreionocrinus patulus* Girty, *H. pentagonus* Miller and Gurley, and *Eupachycrinus platybasis* White.

Occurrence.—Pennsylvanian series (Upper Carboniferous), North America.

Sciadiocrinus? crassacanthus Moore and Plummer, n. sp.

Text-figure 24

Hydreionocrinus sp., MATHER, 1915, Denison Univ. Sci. Lab., Bull., vol. 18, p. 102, pl. 2, figs. 5, 5*a*, 6, 6*a*.

Among crinoid specimens from the Morrow beds, large spinous plates of the type that occurs bordering the summit of the anal sac in hydreionocrinid genera are fairly common. Those here indicated as *Sciadiocrinus? crassacanthus* define a group that can be recognized without difficulty, not only among crinoid fragments from Morrow beds, but also among plates of corresponding type from many higher Pennsylvanian horizons. As indicated by typical examples, the length of these spine-bearing plates ranges from about 20 to 35 mm., the maximum width of holotype, 8.5 mm., of a large paratype, 11 mm. The proximal part of the plates is relatively thick dorso-ventrally; lateral suture faces are strongly excavated, the planes of the outer edges sloping in such manner as to show that the axis of the spine was distinctly down-sloping or pendent rather than horizontal; dorsal surface of plate distinctly longer than ventral, the proximal margin of the latter showing grooves that are probably like the sutural canals of the adjoining anal sac.

A restoration of the summit of the sac in the species represented by these plates is given in the accompanying text-fig. 24, which shows the inferred nature of the top of the sac and the somewhat down-sloping attitude of the spines.

Remarks.—The size of the plates here described indicates a species of hydreionocrinid larger than any yet known as repre-

sented by a dorsal cup from Morrow rocks. It is referred to the genus *Sciadiocrinus* chiefly because of resemblance of the individual spines and of the restored summit of the sac to appearance of these in the genotype, *S. acanthophorus*. Until more complete specimens are available, however, this generic assignment must be considered questionable.

Occurrence.—Brentwood limestone, Morrow subseries, Pennsylvanian (Upper Carboniferous): Loc. 4519, Keough quarry, north of Fort Gibson, Okla.; Loc. 4522, road cuts on U. S. highway 71, opposite Woolsey, Ark., and elsewhere.

Types.—Kansas Univ., holotype, no. 451917; paratypes, nos. 451917*a-i*; both from Loc. 4519.

Sciadiocrinus? sp.

Text-figure 25

A single specimen of an unusually large hydreionocrinid sac spine in our material seems quite different from those identified as *S.? crassacanthus*. The proximal expanded portion of the spine-bearing plate is relatively very short and the suture on the under side at the base is considerably shifted laterally with respect to the upper suture. The spine, which is broken, is nearly 30 mm. long.

Occurrence.—Brentwood limestone, Morrow subseries, Pennsylvanian (Upper Carboniferous); Loc. 4519, Keough quarry, north of Fort Gibson, Okla.

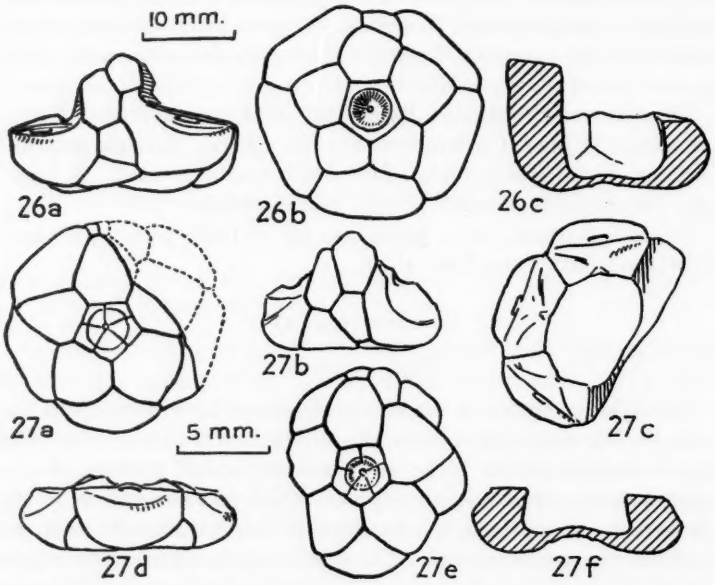
Figured specimen.—Kansas Univ., no. 451919; collected by C. L. Foster.

Genus PLAXOCRINUS Moore and Plummer, n. gen.

Text-figure 26

Dorsal cup very low saucer-shaped; IBB 5, largely covered by stem impressions but not strongly depressed; BB 5, subequal, inter-BB sutures subhorizontal, distal parts of BB nearly horizontal; RR 5, moderately convex or very protuberant, facets less than width of plates, inclined outward; anal plates 3 in dorsal

cup, thick, forming rather prominent protuberance at posterior side of cup. Stem round. Arms and tegmen unknown.



FIGS. 26, 27. THE GENOTYPE OF *Plaxocrinus* AND A SPECIES OF THIS GENUS FROM THE MORROW BEDS

(*26*), Accurate drawings of the holotype of *Plaxocrinus crassidiscus* (Miller and Gurley), from the Missouri subseries at Kansas City; *26a*, posterior view; *26b*, basal view; *26c*, antero-posterior cross-section constructed from holotype, showing convexity of radials and basal concavity. (*27*) *Plaxocrinus strigosus*, n. sp., from the Brentwood limestone near Brentwood, Ark., and Fort Gibson, Okla.; *27a*, basal view of holotype; *27b*, posterior view of a paratype; *27c*, ventral view of holotype, showing relatively broad articular facets and bulbous sides of radials; *27d*, anterior view of holotype; *27e*, basal view of paratype; *27f*, cross-section showing basal concavity and relative thickness of plates.

Genotype, *Hydreionocrinus crassidiscus* Miller and Gurley. This species from the "Coal Measures at Kansas City, Mo.," was collected from an unknown horizon (but most likely the Wyandotte limestone) in the Kansas City group, belonging to the mid-portion of the Missouri subseries (upper middle Pennsylvanian).

Remarks.—The dorsal cup of this genus somewhat resembles that of *Sciadiocrinus*. It is distinguished by the greater flatness, or lesser concavity, of the central part of the base of the cup. The stem impression is moderately deep. A distinctive feature of some species is the strongly protuberant nature of the RR, which are extremely convex in longitudinal profile. The generic name is derived from πλαξ, flat or broad.

In addition to the genotype, *Hydreionocrinus discus* Meek and Worthen and *H. subsinuatus* Miller and Gurley appear referable to this genus.

Plaxocrinus strigosus Moore and Plummer, n. sp.

Plate XIV, figures 1a-f; text-figure 27

Cup low, base gently concave, sides strongly bulging, maximum diameter at about mid-height of cup, holotype, 12 mm., paratype 45203*a*, 12.5 mm., paratype 45224, 11 mm.; height, holotype, 3.8 mm., paratypes approximately the same; diameter body cavity in holotype, 6 mm.; depth of basal depression, 1.2 mm.

IBB 5, forming pentagon about 3.2 mm. in diameter, that makes part of floor of basal concavity, distal margins 0.6 mm. above plane of base of calyx. Proximal parts covered by stem attachment which ranges in diameter from 2.2 mm. in holotype to 1.7 mm. in paratype 45224; stem impression carrying about 22 somewhat coarse radiating crenellae; distal part of IBB sloping gently outward and downward.

BB 5, nearly equal, pentagonal, except pB and rpB which are hexagonal; proximal margins forming border of basal concavity of the cup and distal parts curving outward and upward to about mid-height of calyx.

RR 5, width nearly twice length, rather strongly convex in longitudinal and transverse profile, giving a pentalobate outline to calyx. Articular facets relatively broad, inclined outward at about 40° from horizontal; width of facets in holotype 3.5 mm.; external ligament area rather deeply concave, the outer margin bending in a broad outward loop from angles of plate, maximum width about 1.5 mm.; a narrow deep ligament pit, 1.4 mm. long,

lies next to the transverse ridge, being separated from the external ligament area by a little narrow ridge that extends laterally to points about half way between ends of pit and angles of facets; transverse ridge distinct but not strongly elevated, curving slightly inward in mid-portion; internal part of facet shows the presence of interarticular ligament fossae, obscurely separated from muscular fossae that slope obliquely inward from somewhat strongly elevated lateral borders; adjacent ridged borders of muscle areas on adjoining RR separated by a groove; intermuscular notch shallow; some facets show a fairly distinct intermuscular septum which in other cases carries a narrow furrow leading to a small rounded pit just inside the transverse ridge and closely adjoining external ligament pit; this small rounded pit may be remnant of the central canal.

Anal plates not preserved in holotype or paratype 45203*a*, but in paratype 45224 these plates appear to be normal for the genus, an elongate RA lying between pB and rpR, touching rpB below, and supporting anal x and rt above; the two latter plates are about the same in size and in elongate outline as RA.

Surface ornamented by numerous distinct granules. Sutures distinct, very slightly impressed.

Remarks.—This species is distinguished by the protuberant character of RR, giving the cup a somewhat distinctive pentalobate form, by the granulose ornamentation and by characters of the facets. No other Morrow crinoid of even approximately similar characters has been observed. *P. crassidiscus* (Miller and Gurley) from beds of Missouri age at Kansas City shows a strong convexity of the RR but there are noteworthy differences in shape, and the granulose ornamentation is much finer than in the Morrow species.

Occurrence.—Brentwood limestone, Morrow subseries, Pennsylvanian series (Upper Carboniferous); Loc. 4520, Keough quarry, sec. 36, T. 16 N., R. 19 E., about 2 miles north of Fort Gibson, Okla.; Loc. 4522, highway cut on U. S. 71, opposite Woolsey, Ark.

Types.—Kansas Univ., holotype, no. 45203, and paratype, no. 45203*a*, from Loc. 4520; paratype, 45224, Loc. 4522; specimens collected by R. C. Moore.

Genus PERIMESTOCRINUS Moore and Plummer, n. gen.

Text-figure 28

Dorsal cup low bowl-shaped with flaring sides, base with sharply impressed concavity; IBB 5, small, mostly covered by stem attachment, at bottom of basal concavity; BB 5, proximal part included in basal concavity but main part forming outer lower slope of cup, subequal; RR 5, facets sloping outward, slightly less than width of plates; anal plates 3, x and rt projecting above summit of RR. Arms only partly known; IBr_1 axillary, IIBr quadrangular, uniserial, no branching observed above IBr. Anal sac unknown. Stem round.

Genotype, *Hydreionocrinus nodulifer* Miller and Gurley. This species was collected from an unrecorded horizon (probably Wyandotte limestone) in the Kansas City group of the Missouri subseries (upper middle Pennsylvanian) at Kansas City, Mo.

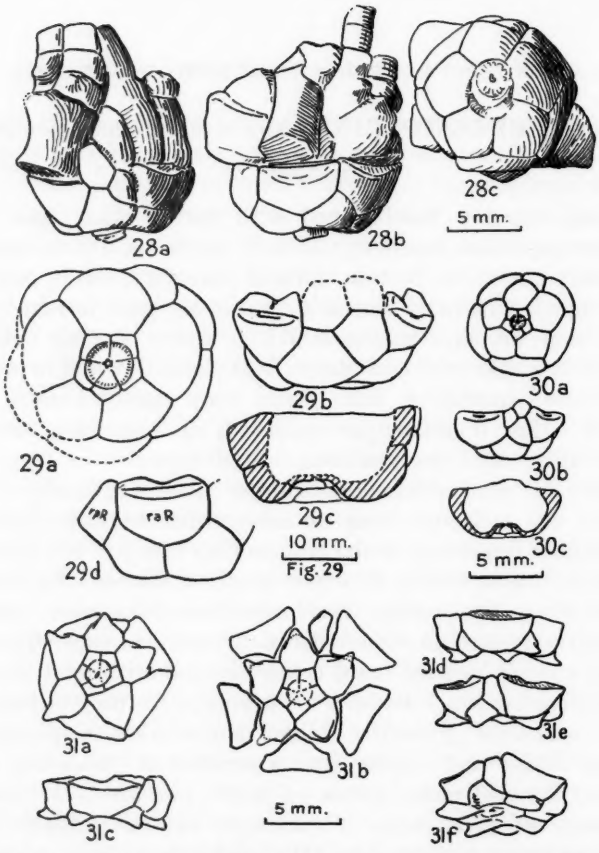
Remarks.—The genus *Perimestocrinus* (περιμεστος, full all around) is erected to receive distinctly rounded cups with small rather sharply defined basal concavity and with anal plates as in *Hydreionocrinus*. Besides the genotype we may include here *Hydreionocrinus granulifer* Miller and Gurley, *Eupachycrinus parvus* Miller and Gurley, and a number of previously undescribed Pennsylvanian forms, of which two from the Morrow subseries are given here. *P. nodulifer* has one axillary IBr in each ray and 4 quadrangular IIBr following, without evidence of further branching. Although anal sac and complete arm structure are not known, the shape of the dorsal cup, including especially the narrowly restricted rather sharp basal concavity, affords sufficient basis for discrimination of the genus.

Occurrence.—Pennsylvanian (Upper Carboniferous), North America.

Perimestocrinus pumilis Moore and Plummer, n. sp.

Plate XIV, figures 10a-c; text-figure 29

Calyx of medium size, relatively deep, with excavated flat base and steeply flaring sides, stem impression 1.8 mm. above



FIGS. 28–31. THE GENOTYPE OF *Perimestocrinus* AND SPECIES OF THIS NEW GENUS FROM MORROW BEDS, ALSO *Utharocrinus*

(*28*), *Perimestocrinus nodulifer* (Miller and Gurley), the genotype, from the Missouri subseries at Kansas City; accurate drawings of the holotype; *28a*, posterior view of crown showing rounded cup with small basal concavity and simple branching arms; *28b*, anterior view; *28c*, basal view, the attached stem fragment nearly filling the basal concavity which does not extend beyond the proximal edge of the basal circlet. (*29*), *Perimestocrinus pumilis*, n. sp., from the Brentwood limestone near Fort Gibson, Okla.; *29a*, basal view of holotype; *29b*, posterior view of same; *29c*, antero-posterior cross section showing relations of small basal concavity; *29d*, view of right anterior ray. (*30*), *Perimestocrinus teneris*, n. sp., from the Brentwood limestone, Woolsey, Ark.; *30a*, basal view of holotype; *30b*, posterior view of same; *30c*, cross section of cup showing small basal concavity. (*31*), *Utharocrinus pentanodus* (Mather), from the Brentwood limestone near Fort Gibson, Okla., accurate drawings of the holotype; *31a*, basal view showing spine-bearing basals; *31b*, analysis of plates of the cup showing their slightly irregular form and especially the asymmetrical shape and position of the anal plate; *31c*, left posterior radial view; *31d*, anterior view; *31e*, posterior view; *31f*, oblique view from below showing very gentle, broad basal concavity.

plane of base of calyx. Diameter of holotype 19 mm., height, measured from basal plane of calyx to transverse ridge of aR, 7.0 mm.

IBB 5, forming summit of basal depression, the IBB circle a regular pentagon, 5.5 mm. in diameter in holotype, mostly covered by stem impression, 4.0 mm. in diameter; distal extremities sharply flexed from plane of stem attachment; distal margin of IBB 1 mm. above basal plane of calyx in holotype.

BB 5, pentagonal, except pB and rpB which are hexagonal, strongly convex, proximal portions forming part of basal depression and distal portions curved to form lower outer part of calyx, also moderately convex transversely, appearing somewhat bulbous.

RR 5, about twice as wide as long, outer face flaring upward, nearly straight in longitudinal profile but curving strongly transversely. Articular facets directed strongly outward, with nearly plane surface inclined about 60° to the horizontal; length of facet dorso-ventrally in holotype 4.4 mm., transverse ridge distinct, width of external ligament area about 1.9 mm., ligament pit deep 2.2 mm. long, about 0.65 mm. wide; internal ligament areas strongly defined; ambulacral groove deep and narrow, extending to inner margin of transverse ridge; facets occupy slightly less than maximum width of RR, so that the interradial sutures are bordered by sloping surfaces extending from the facets to them.

Anal series consists of moderately large pentagonal RA in normal position, resting on pB and rpB; directly above pB and obliquely above RA, holotype shows position of anal x but this plate is missing, as is also rt, the position of which is indicated by facets above RA and at left of rpR.

Surface apparently smooth but there is faint suggestion in holotype of occurrence of fine granules on some of the plates. Arms and tegmen unknown.

Remarks.—This species has the general shape of *Cibolocrinus tumidus* which is associated with it, but the entirely different structure of the anal region, much greater thickness of plates and difference in the articular facets show readily that it is altogether

different. The form is unlike *Perimestocrinus teneris* in size and shape, including especially the relatively high steep sides of the cup that are here seen. From *P. granulifer* (Miller and Gurley), from beds of Missouri age, this species is distinguished by the more bulbous character of the plates and by absence of well-marked ornamentation.

Occurrence.—Brentwood limstone, Morrow subseries, Pennsylvanian (Upper Carboniferous); Loc. 4521, Braggs Mountain, along state highway about 3 miles southeast of Fort Gibson, Okla.

Type.—Kansas Univ., holotype, no. 45213; collected by R. C. Moore.

Perimestocrinus teneris Moore and Plummer, n. sp.

Plate XIV, figures 5a-c; text-figure 30

Calyx low, subconical, less depressed than most forms referred to this genus, base with moderately strong concavity about 0.8 mm. deep, sides of the concavity sloping uniformly at an angle of about 45° to vertical axis of the cup; outer sides of calyx slope upward at an angle of about 50° to the vertical axis. Maximum diameter, near summit of radials, 8.5 mm., height of cup, 3.5 mm.

IBB 5, sutures distinct but not impressed; the circlet of these plates forms a strongly defined regular pentagon that lies entirely within the basal concavity of the calyx; proximal part of plates covered by round stem impression which in the holotype is 0.9 mm. in diameter and shows a relatively large round axial canal; distal part of plates flexed sharply into sloping plane of the sides of basal depression.

BB 5, nearly equal, pentagonal, except pB which shows a short additional edge distally; proximal narrow zone very sharply bent to form union with IBB, the main part of plate being placed to form lower outer slope of cup, each plate slightly convex, sutures clearly marked.

RR 5, approximately equal, wider than long, strongly convex in longitudinal profile with maximum curvature slightly below margin of articular facet, more gently convex transversely.

Articular facets gently concave sloping somewhat outward, divided by fairly strong transverse ridge into outer area, the external ligament fossa, which has maximum width of 0.4 mm. and contains centrally at inner margin a deep elliptical ligament pit; and an inner area in which the inter-articular ligament fossae and muscular attachment fossae are obscurely differentiated, intermuscular notch appears to be moderately distinct.

Three anal plates are present on the posterior side of the calyx; a large subquadrangular RA adjoins pB along all of its right upper margin and supports rpR at its right; above it is rt and at its left, anal x. The anal x and rt are small plates whose upper margins extend above the line of the ummit of the RR.

Surface smooth.

Remarks.—This diminutive crinoid shows typical features of *Perimestocrinus*. The basal concavity is smaller and relatively deeper than that of *P. parvus* (Miller and Gurley) and the outer slopes of the calyx are higher and more evenly flaring in *H. teneris*. This new species most closely resembles an undescribed form from the Wyandotte limestone at Kansas City, but is smaller, has less convex plates, and shows other differences which make distinction without difficulty.

Occurrence.—Brentwood limestone, Morrow subseries, Pennsylvanian (Upper Carboniferous); Loc. 4522, road cut on U. S. Highway 71, opposite Woolsey, Ark.

Types.—This species is described on the basis of a single well-preserved specimen; holotype, Kansas Univ., no. 45221; collected by R. C. Moore.

Genus UTHAROCRINUS Moore and Plummer, n. gen.

This new genus is introduced to contain *Delocrinus pentanodus* Mather which is designated as genotype, and possibly other forms having the peculiar features of the cup shown by this species. As indicated in the revised description of the genotype species, this form seems rather to belong in association with *Hydreionocrinus* and allied genera, here indicated, than with *Delocrinus*. Since *U. pentanodus* is at present the only representative of this genus, its characters are sufficiently indicated by description of

the genotype. The name of the genus is derived from *ουθαρ*, udder or breast, referring to the projections from the base of the cup.

Genotype, *Delocrinus pentanodus* Mather.

Occurrence.—Morrow subseries, Pennsylvanian (Upper Carboniferous); northeastern Oklahoma.

Utharocrinus pentanodus (Mather)

Text-figure 31

Delocrinus pentanodus MATHER, 1915, Denison Univ. Sci. Lab., Bull., vol. 18, p. 106, pl. 3, figs. 8, 8*a*, *b*. Morrow formation, near Fort Gibson, Okla.

Mather's description:

Dorsal cup small, low, basin-shaped, with slightly concave base and no constriction at upper margin of radials; infrabasals five, suture lines scarcely discernible, projecting well beyond the shallow circular depression of the stem attachment; basals five, pentagonal in outline, the posterior basal hexagonal because of truncation for the anal plate, gently convex transversely and longitudinally throughout the greater part of each plate but abruptly deflected upward near the acute outer angle, each plate bearing a single, massive, sub-centrally situated, horn-shaped node protruding outward and curving laterally from just within the flattened basal portion of the cup, radials pentagonal, broader than high, comparatively thick and massive, strongly convex longitudinally, more gently convex laterally, central portion thickened and tumid, upper surface truncated and faceted for attachment of primibrachs; anal plate small, quadrilateral, resting upon the truncated edge of the posterior basal between the posterior radials; body cavity shallow, cylindrical; arms and ventral disc unknown.

The dimensions of the holotype are: outside diameter of dorsal cup, 8.8 mm.; height of dorsal cup, 2.5 mm.; diameter of body cavity, 4.4 mm.; depth of body cavity, 1.7 mm.

Additional observations.—Careful study of Mather's holotype indicates that the arrangement of plates, and in part the shape of certain plates are not rightly shown in Mather's (1915, p. 107) diagram of the calyx. Also, the true structure of this interesting fossil cannot be discerned from the very small and inadequate figures on Mather's plate of illustrations. Instead of the entirely symmetrical disposition of the spine-bearing BB, alternating with the RR of even size and shape, all of these plates are somewhat irregular, the BB being in general slightly shifted toward the left from an exact interradial position. Thus, the basal

circlet appears slightly rotated with respect to that of the RR. The lateral displacement is especially marked in the case of pB and rpB. The pB is broadly in contact with lpR and an approximately equal space along the upper right margin of pB is in contact with an anal plate located between the two posterior RR. This anal plate thus projects downward almost to the lowermost angle of rpR and along almost all of the upper right margin of pB, lacking only a fraction of a millimeter of touching rpB (see text-fig. 31). Mather indicates only a very slightly oblique and short suture between this anal plate and pB.

Remarks.—The strong obliquity in position of the anal plate of this species and the very shallow depression of the IBB are not at all in accord with assignment of this crinoid to *Delocrinus*. No undoubted representative of *Delocrinus* shows an anal plate with an obliquely placed suture separating it from pB. It is the uniform rule in *Delocrinus* that this lower suture either truncates the distal margin of pB squarely, or in cases where the anal plate barely touches or is separated from pB, its lower end is symmetrically pointed. The arrangement of plates is like that in hydreionocrinid genera except for the fact that only one anal plate appears in the calyx, whereas at least three plates of the anal series are commonly present in *Hydreionocrinus* and allied genera, partly or entirely below the upper margin of the RR. The large plate at the base of this series, which lies between pB and rpR, is RA. The relatively large, obliquely placed anal plate in this Morrow species is undoubtedly the RA and the two plates which normally belong next above it are, in this case, pressed slightly above the upper margin of the dorsal cup and are not preserved. Indication that these plates were existent is found in two depressions at the upper margin of the inferred RA.

Even more convincing as to the correctness of the interpretation that has been given is a comparison of the Morrow form with certain undescribed species from higher Pennsylvanian horizons in our collection. These latter specimens, like *U. pentanodus*, bear more or less well-developed spines or nodes on the basals. The two species that show best developed spines, have RA exactly in the position of this plate in *pentanodus*.

Above RA and above the upper margin of the RR, are two additional plates of the anal series, anal x and rt. If these latter two plates were lacking, the plan of the calyx would show precise correspondence to that of *pentanodus*.

Occurrence.—"Morrow formation, shaly member above heavy limestone, 1½ miles north of Fort Gibson, Okla., in sec. 35, T. 16 N., R. 19 E."

Type.—Holotype (and only known specimen), Chicago Univ. Walker Mus., 16181; collected by Stuart Weller and L. C. Snider.

SECTION IV.—GENERA WITH LOW BASIN-LIKE CUP CONTAINING ONE ANAL PLATE OR LACKING ANAL IN CUP

Three known species of Morrow crinoids represented by cups may be referred to this group. One of these is the common and very distinctive form that has been described under the name *Delocrinus dubius*. This species and an associated new form are actually separable from *Delocrinus* on the basis of absence of an anal plate (except very rarely in "*D.*" *dubius*), although both have the characteristic calyx form of *Delocrinus*. A new genus, *Paradelocrinus*, is made to include these species. An interesting group of snub-nosed IBr spines is tentatively referred to *Paradelocrinus*. In addition, there is a true species of *Delocrinus*.

Notes on the new genera *Stuartwellercrinus* and *Paraplasocrinus*, introduced as consequence of necessary emendation of *Cibolocrinus* Weller, are appended.

Genus DELOCRINUS Miller and Gurley, 1890

The distinguishing features of this genus are found in the form and structure of the dorsal cup and in the nature of the arms. The cup is low, the height being commonly less than half of the width, and at its base is a relatively strong concavity that involves the proximal part of the BB as well as the IBB, the latter being 5 in number, small, and largely covered by the stem attachment; a single anal plate, called x, separates the posterior RR, generally resting on the squarely truncated tip of pB. The arms branch once on IBr_1 and are biserial.

Genotype, *Poteriocrinus hemisphericus* Shumard

Remarks.—*Delocrinus* is very abundantly represented in the crinoid faunas of the Upper Carboniferous and Lower Permian rocks of the Mid-Continent region. Approximately 600 dorsal cups and crowns in our present collection belong to this genus, and despite relative simplicity of plan of the cup, numerous species, largely undescribed, are recognizable. Examination of the literature indicates failure in some cases to apprehend the true character of *Delocrinus*, which is really a very well differentiated generic entity, not to be confused with such genera as *Graphiocrinus* or *Erisocrinus* even in cases where fragmentary cups alone are at hand. The plate arrangement in the three genera mentioned is identical, except that in *Erisocrinus* an anal plate does not enter the dorsal cup. *Graphiocrinus* is distinguished from *Delocrinus* by absence in the former of a funnel-like basal concavity, by difference in the arms and the fact that cups belonging to *Graphiocrinus* are very diminutive on the average as compared with *Delocrinus*. *Erisocrinus* lacks a strongly marked basal concavity.

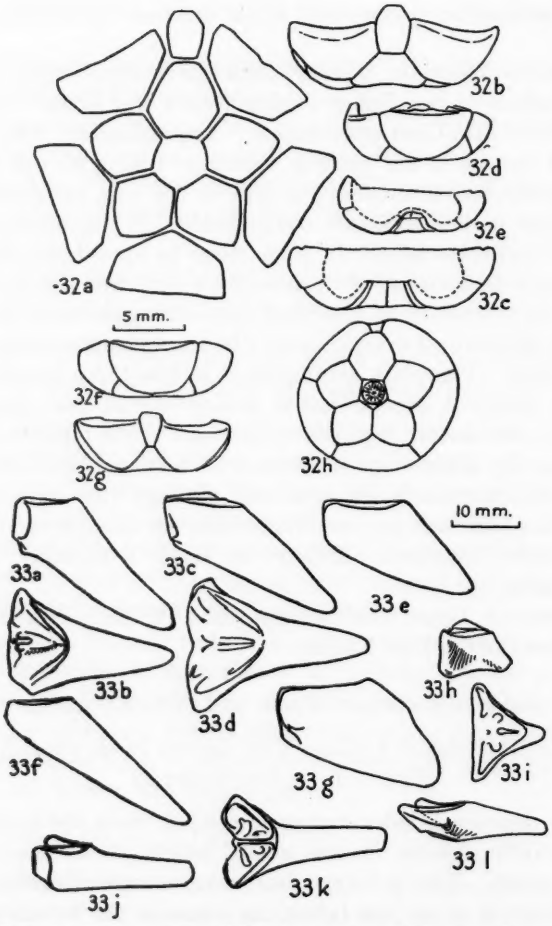
Occurrence.—Upper Carboniferous and Permian, North America, Timor (Dutch East Indies).

Delocrinus matheri Moore and Plummer, n. sp.

Plate XIII, figure 3; plate XIV, figures 7a–d; plate XVI, figures 1a–c; text-figure 32

Calyx depressed, sides flaring somewhat more distinctly than in most other species of this genus, height about one-third of width, small. The holotype has a maximum diameter of 15 mm., which is at or just below the plane of the summit of the RR; height 4.5 mm. A smaller specimen, which is a paratype, has a maximum width of 11 mm., and a height of 3.5 mm. Central part of base depressed in a steep-sided funnel of moderate depth.

IBB 5, forming base of the funnel at bottom of calyx; most of length of the plates is in the area of the circular stem attachment, less than 1 mm. of the distal part being inflected to make the basal wall of the funnel; diameter of stem impression in small



FIGS. 32, 33. SPECIES OF *Delocrinus* FROM THE MORROW BEDS

(*32*), *Delocrinus matheri*, n. sp.; *32a*, analysis of plates of the cup, holotype, the IBB circlet missing; *32b*, posterior view of holotype showing large anal x; *32c*, cross section showing basal concavity, holotype; *32d*, right anterior view of paratype; *32e*, antero-posterior cross section of paratype; *32f*, anterior view of paratype; *32g*, posterior view of paratype showing narrow anal x; *32h*, basal view of paratype. (*33*), *Delocrinus? pendens*, n. sp., and *Delocrinus?* sp. A, B, C; *33a, b*, side and top views of holotype spine of *D.? pendens*, latter somewhat foreshortened because upper facets are held horizontal; *33c, d*, a paratype; *33e*, a short spine, a paratype; *33f*, a very long paratype; *33g*, a short thick spine questionably included in *D.? pendens; 33h, i, Delocrinus?* sp. A; *33j, k, Delocrinus?* sp. B; *33l*, Delocrinus? sp. C.

paratype, 1.2 mm. The IBB are not preserved in the holotype, the position of attachment of the IBB disk being indicated by the edges of the BB.

BB 5, nearly equal, the pB slightly larger than the others and hexagonal instead of pentagonal, strongly convex longitudinally, the proximal portion forming the walls of the funnel-like depression at base of the calyx and the distal portion curving to about the mid-height on the side of the calyx; this curvature is shown in the accompanying figures of cross-section through the calyx. The depth of the funnel to the margin of the BB in the holotype is 1.8 mm.; the total depth of the funnel in the small paratype is 1.3 mm. A slight concavity in lateral profile is most noticeable in the proximal portion of the BB, the distal portion being slightly but regularly convex.

RR 5, pentagonal, width twice the height, maximum width at the summit, surface of plate sloping outward to a point near the top where it is sharply rounded toward interior. Articular facets with characters typical of the genus; the ligament area outside the fairly prominent cross ridge deep and narrow; prominent radially disposed ridges near the interradial sutures.

Anal x, hexagonal, height two or more times greater than width; rests on truncated distal margin of pB; about one-third of its length above the line of RR, this part curving rather sharply inward.

Surface of all plates marked by a delicate but very well-defined shagreen consisting of irregularly winding fine ridges and depressions.

Remarks.—This species is very readily separated from *Paradelocrinus dubius* with which it is associated by its size, shape, and ornamentation. The outline of the calyx is similar to that of various species from other horizons, but the ornamentation described has been seen in no other form.

Occurrence.—Brentwood limestone, Morrow subseries, Pennsylvanian (Upper Carboniferous); Locs. 4519, 4520, Keough quarry, sec. 36, T. 16 N., R. 19 E., north of Fort Gibson, Okla.

Types.—Kansas Univ., holotype, no. 45202, collected by R. C. Moore; paratype, no. 45196, collected by C. L. Foster; both from the locality north of Fort Gibson.

Delocrinus? pendens Moore and Plummer, n. sp.

Text-figure 33

Crinoid plates, MATHER, 1915, Denison Univ. Sci. Lab., Bull., vol. 18, p. 109, pl. 2, figs. 4, 4*a*.

As noted by Mather, a pointed type of IBr spine is common in the Brentwood limestone. Typical examples are illustrated in text-figure 33 *a-d*; less common forms that are here considered as variants of the so-called typical form include longer (text-fig. 33 *f*) and shorter (33 *e*, *g*) spines, all of which agree in the distinct downward slope of the ventral (upper) surface of the spine when the upper articular facet area is disposed horizontally. The general plane of the facet for articulation with the radial plate is approximately at right angles to that of the facets for articulation with IIBr. The total length of an average specimen (text-fig. 33 *a*) is 20 mm. Many of the spines appear to be smooth, but this is probably due to condition of preservation, for examination commonly shows traces of a delicate ornamentation that resembles the fine, irregular markings on the cup plates of *Delocrinus matheri;* on some spines this ornamentation is fairly well preserved.

Remarks.—The spines here described are designated under a separate specific name, first, because they can be recognized as distinct entities in the Morrow crinoid fauna and because they appear to be readily distinguishable from numerous types of primibrach spines from other Pennsylvanian horizons; and second, because there is now only supposition to indicate that they may belong to *D. matheri.* When the crown to which they belong is learned definitely, the name *pendens* will necessarily be thrown into synonymy if the species represented by such crown is already described, and if the crown proves to differ from described species it will have to be designated by the specific term that is here applied to the primibrach plates. That these plates are best referred to *Delocrinus* is indicated by their resemblance to the form of corresponding plates in many species of this genus, and also by the resemblance of the surface ornamentation to that of *D. matheri,* as already noted. Too much reliance can-

not be put on this comparison of decoration, since it is observed that several species of Morrow crinoids possess rather similar delicate surface markings. Mather thought that the spines here under discussion might belong to *"Delocrinus" dubius*, which is placed by us in *Paradelocrinus*. Because ornamentation very much like that of our spines occurs in *Paradelocrinus*, one cannot be certain that the spines belong to *Delocrinus*.

Occurrence.—Brentwood limestone, Morrow subseries, Pennsylvanian (Upper Carboniferous); Loc. 4519, Keough quarry, north of Fort Gibson, Okla.; Loc. 4522, road cuts on U. S. highway 71 near Woolsey, Ark.; and elsewhere.

Types.—Kansas Univ., holotype, no. 451920 (text-fig. 33*a, b*); paratypes, nos. 451920*a-u*; from Loc. 4519.

Delocrinus? sp. A

Text-figure 33 *h, i*

A few examples of a primibrach with very short, sharp-pointed spine are contained in our material from Keough quarry near Fort Gibson. They are not sufficiently distinctive to warrant specific differentiation.

Figured specimen.—Kansas Univ., no. 451921 (text-fig. 33 *h, i*).

Delocrinus? sp. B

Text-figure 33 *j, k*

A form of primibrach spine that is readily distinguished from *D?. pendens* is illustrated in Text-figure 33*j, k*. The axis of the spine is parallel to the plane of the upper articular facet, the broken tip indicates an unknown greater length.

Figured specimen.—Kansas Univ., no. 451922 (text-fig. 33*j, k*), Brentwood limestone, Keough quarry, near Fort Gibson, Okla.

Delocrinus? sp. C

Text-figure 33 *l*

Another type of primibrach spine that is very doubtfully referred to *Delocrinus* is distinguished by the strongly acute angle

between the lower and upper articular facets. The width of this spine at the base is slightly greater than that of the figured *Delocrinus?* sp. B.

Figured specimen.—Kansas Univ., no. 451923 (text-fig. 33 *l*); Brentwood limestone at Keough quarry, near Fort Gibson, Okla.

Genus PARADELOCRINUS Moore and Plummer, n. gen.

Dorsal cup as in *Delocrinus* Miller and Gurley but lacking an anal plate as an element below the upper edge of the cup. Stem round. Arms and tegmen unknown.

Genotype, *Paradelocrinus aequabilis* Moore and Plummer, n. sp.

Remarks.—It is possible that *Delocrinus dubius* Mather might have been selected as the genotype of *Paradelocrinus* and that such selection would have indicated with satisfactory clearness the characters that are regarded as distinguishing this new genus. The fact that the holotype of Mather's species shows anal x actually entering the dorsal cup, though ever so slightly, is, however, a potential source of misunderstanding. It is clearly indicated from our study that this holotype is a very exceptional rather than a normal example of the species. Unfortunately, moreover, the published diagram of the dorsal cup (Mather, 1915, p. 105) gives an erroneous idea of the extent to which the anal plate in this abnormal specimen descends below the summit of the radials. An accurate drawing of the posterior side of the holotype (Text-fig. 34*a*) shows that the anal barely notches the line of radial summits and is not at all typical of the condition that is normal in *Delocrinus*. Taken in conjunction with the evidence furnished by numerous other specimens, no importance at all is attached to the exception that the holotype presents.

Paradelocrinus is distinguished from *Erisocrinus* by the presence of a funnel-like basal concavity in the former, and almost invariably, also, by well marked differences in contour of the dorsal cup as seen in side view.

Occurrence.—Pennsylvanian (Upper Carboniferous); Mid-Continent region, United States. The two species here given are the only ones yet described, but the genus appears to be represented also at certain higher horizons.

Paradelocrinus aequabilis Moore and Plummer, n. sp.

Plate XIV, figures 4a–e; text-figure 35.

Calyx somewhat small, low; maximum diameter at summit of RR, 10.9 mm. in holotype, nearly four times height of calyx, which is 2.9 mm. in holotype; with strong basal depression, the stem attachment being 1.7 mm. above the plane of base of calyx.

IBB 5, forming about half of height of basal depression, a little less than half of length of each plate covered by stem impression, distal part flaring outward at angle of about 45°; distal margins form a regular pentagon 0.9 mm. above plane of base of calyx.

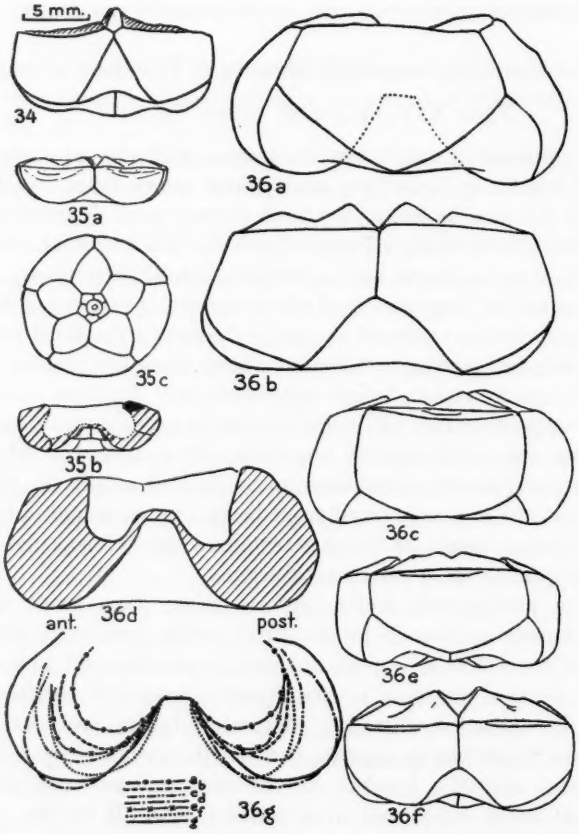
BB 5, nearly equal, length approximately same as maximum width, all pentagonal; pB is identifiable in basal view of calyx by its larger size, for it slightly but distinctly exceeds the other BB in length and width; distal extremities lie well within the circumference of the cup as viewed from below; longitudinal curvature fairly regular, height of distal extremities above basal plane only slightly greater than proximal margins.

RR 5, pentagonal, width slightly more than twice length, rather evenly convex in longitudinal profile, proximal points in plane of base of cup, sloping outward in middle part to approximately vertical position in distal parts, inter-RR sutures slope distinctly outward distally. Articular facets not well preserved in types but it appears that their median plane is nearly horizontal and the borders of the muscle areas rise sharply; width of facet, measured from outer face of R to line joining inner points of muscle areas, is 2.8 mm. in holotype; width of external ligament area, 0.6 mm. in holotype; ligament pit, 0.7 mm. long, strongly indents and partly interrupts transverse ridge which is sharp-crested and bears fine denticles.

Anal x does not extend below summit of RR, but is identifiable as small inserted sub-triangular plate near inner margin of facets between lpR and rpR.

Surface smooth, sutures not impressed.

Remarks.—The absence of anal x in all observed specimens of *P. aequabilis* suggests comparison with the associated *P. dubius* which is also distinguished by this character. The form of the calyx and its size in adult specimens of *P. dubius* are so different



FIGS. 34–36. SPECIES OF *Paradelocrinus*, N. GEN., FROM MORROW BEDS

(*34*), Posterior view of the holotype of *Paradelocrinus dubius* (Mather) showing anal x slightly notching the edges of posterior radials. (*35*), *Paradelocrinus aequabilis*, n. sp., genotype of *Paradelocrinus;* *35a*, posterior view of holotype, the notch at inner border of posterior radials indicating position of anal x; *35b*, cross section of cup showing deep basal funnel and (at right) the position of anal x (solid black); *35c*, basal view of holotype. (*36*) *Paradelocrinus dubius* (Mather); *36a, b*, anterior and posterior views of a very large hypotype (Kansas Univ., no. 45223); *36c*, anterior view of a metatype (Univ. Chicago, no. 16662); *36d*, anteroposterior cross section of a hypotype (Kansas Univ., no. 45191) showing extreme thickness of plates and great depth of basal funnel; *36e, f*, anterior and posterior views of a metatype (Univ. Chicago, no. 16662) having nearly vertical sides and showing notch for anal x above border of RR; *36g*, profiles of the basal concavity in several examples of *P. dubius* showing considerable variation of this feature.

that further comparison is needless; that *P. aequabilis* is not at all a young stage of *P. dubius* is shown by comparison with cups definitely assignable to the latter species that are about the same in size as observed examples of *P. aequabilis*; peculiarities of *P. dubius* are apparent even in the most diminutive specimens. The general form and appearance of *P. aequabilis* suggest a *Delocrinus* stock that is widespread and abundantly represented in later Pennsylvanian beds, especially of the Missouri subseries. *D. missouriensis* Miller and Gurley, among described forms, most closely resembles this Morrow species, but it is larger, has anal x below the upper line of RR, has proportionately much larger BB and is distinguished by other details.

Occurrence.—Brentwood limestone, Morrow subseries, Pennsylvanian (Upper Carboniferous); Loc. 4522, road cuts on U. S. Highway 71 opposite Woolsey, Ark.; collected by R. C. Moore. Two or three specimens from the Brentwood limestone near Fort Gibson, Okla., that are too poorly preserved for accurate determination probably belong to this species.

Types.—Kansas Univ., holotype, no. 45222; paratype, no. 45222*a*; both from Loc. 4522.

Paradelocrinus dubius (Mather)

Plate XIII, figures 2a–c; text-figure 36

Delocrinus dubius MATHER, 1915, Denison Univ. Sci. Lab., Bull., vol. 18, p. 105, pl. 3, figs. 7, 7a, b. Brentwood limestone, near Fayetteville, Ark.

Mather's description:

Dorsal cup below medium size, depressed bowl-shaped, base deeply concave, upper margin constricted, greatest diameter about midway of the height; infrabasals situated at the bottom of the deep funnel formed by the concavity of the base, concealed by the column; basals five, pentagonal, the posterior basal longer than the others but not truncated above for the attachment of the anal plate, the lateral and anterior basals with length slightly greater than width, all strongly and regularly convex longitudinally and moderately concave transversely; radials comparatively thick and massive, the two posterior ones hexagonal, the other three pentagonal in form, strongly convex longitudinally, moderately convex transversely, nearly twice as wide as high, truncated and faceted above for the attachment of the primibrachs; anal plate small, pentagonal, nearly three times as long as wide, resting upon the truncated angles of the two posterior radials and situated in the main above the radials, only the lower one-fourth of

its length being within the dorsal cup, its surface sloping strongly toward the centre of the ventral sac, and reclining at an angle of about 45° with respect to the axis of the calyx; arms and ventral sac unknown.

The dimensions of the individual selected as the holotype are: outside diameter of dorsal cup, 15.8 mm.; diameter of periphery of upper margin of dorsal cup, 13.4 mm.; diameter of body cavity, 7.4 mm.; height of dorsal cup, 5.5 mm.

Additional observations.—The outstanding feature of the calyx as a whole is the prominence and somewhat angular protuberance of the areas at or near the lower points of the RR. If the calyx is placed, lower side down, on a table, it touches the plane of the table top only in five very small areas which are located at the proximal tips of the RR; this peculiarity can be seen readily by pressing the base of the cup very lightly against a perfectly plane surface of plasticene, the points of contact being then marked by five tiny depressions in the smooth plasticene. In some specimens the sutures between the RR and BB, and the distal parts of the inter-BB sutures are sufficiently elevated to make these lines appear distinctly angular. The RR tend to flatness, although in large, presumably old, specimens there is a distinct swelling of the lower part of these plates so as to produce an inward slope of the upper parts. The BB, though strongly convex longitudinally are moderately to very distinctly concave transversely, especially in the distal portions. No other described species shows these peculiarities of geometrical form so strikingly.

The stem impression is small, about 2 to 2.5 mm., and round; it is marked by fine radiating grooves and ridges for articulation with the first stem segment; the axial canal is round and about 0.2 mm. in diameter. The stem impression is at the bottom of a strikingly deep and narrow funnel that comprises the central basal part of the calyx. The depth of this concavity from the plane of the lower tips of the RR ranges from about 4 to 7 mm. and in some cases is only a little less than the height of the calyx. This means that, as in *Delocrinus excavatissimus* Wanner from Permian of Timor and a few upper Pennsylvanian and lower Permian forms from North America, the basal concavity of *P. dubius* rises nearly to the plane of the upper margin of the RR.

The five IBB form the apex of the funnel-shaped basal con-

cavity, but, contrary to Mather's statement, only the proximal portion of them is covered by the stem attachment; the distal part is inflected nearly at right angles to the plane of the stem impression, forming the sides of the funnel near its tip. The sutures between the IBB and BB make a nearly smooth line that encircles the concavity about 1.5 mm. from the border of the stem impression. Each IB is distinctly higher than wide.

The BB are pentagonal, the suture in contact with the IBB being very short (1.5 to 2 mm.) and the other four much longer and nearly equidimensional; the inter-BB sutures are very slightly longer in general than the B-R sutures. The height of BB, measured along the curvature, is slightly greater than the width but in some cases they are nearly equal. The pB is slightly but distinctly narrower than the other BB and it is also a little shorter, although the holotype, as noted by Mather, shows a slightly greater length than the others.

In most specimens the RR are a little less than twice as wide as long. An unusually large specimen (g in Table) in our collection shows, however, a height of RR, measured along curvature, that is 85 per cent of the width. The proximal or lower part of these plates, curves somewhat abruptly inward to meet the BB, but the upper or main part is nearly vertical or slopes upward and inward. The greatest diameter of the calyx is at the mid-height of the RR, and in some specimens this is very distinctly greater than the diameter at the summit of the RR. A faint ridge, curved gently downward in its mid-portion, extends from one upper angle to the other on each R, dividing the articular surface from the lateral face of the plate. The thickness of the RR is extraordinary. One specimen has plates 7.5 to 8 mm. thick, which is greater than the maximum height of the RR in this individual. This unusual thickening, most pronounced in the RR, reduces the body cavity to a rather small part of the total volume of the cup.

No external ornamentation is described by Mather, probably for the reason that the specimen selected as holotype is worn smooth, and other specimens in his collection were not cleaned. Some of these latter show clearly a delicate pattern of granuled

ridges somewhat resembling the whorls of the skin on fingers. There are 5 or 6 of these low ridges in 1 mm. On the RR they have a fairly definite trend at right angles to the sutures between RR and BB, and on the BB they have an approximate longitudinal trend, but this is not strongly defined.

The articular facets of the RR are about 3.5 to 5 mm. in width and, unlike most species of *Delocrinus*, the general planes of the facets slope distinctly outward. Each facet is divided into two unequal areas by a strong straight ridge that extends from one upper angle of the R to the other; the sides of the ridge bear minute teeth disposed at right angles to the ridge. On the outer side of the ridge is a narrow gently concave ligament area, bounded externally by the faint curving ridge already mentioned as defining the upper limit of the lateral face of the RR. Centrally located in the ligament area is a deep narrow pit, 1.0 to 1.5 mm. in length; between this pit and the main cross ridge are two faint short slits, one on each side of the midpoint of the groove. Inside of the transverse ridge is the proportionally broad muscle area which is divided into two parts on each facet by a deeply cleft ambulacral groove. Next to the ends of the ridge on the inner side is a very distinct but shallow groove, the interarticular ligament fossa, that lies parallel to the ridge; this fossa reaches only part way toward the ambulacral groove at the centre of the facet. Finally, a groove-like depression is observed at the junction of each of the RR facets.

We have seen no example other than the holotype of *P. dubius*, in which the anal plate enters the dorsal cup. Commonly this plate is seen to have been forced entirely above the line of the RR, its position being indicated both by the more strongly elevated area at the junction of the posterior RR facets and by the vestige of the anal plate (or a notch marking its location) at the inner margin of these facets. The position of the anal plate can be found in each specimen to occur in the inter-radius coinciding with that of the narrowest basal plate.

Measurements of the holotype and a few other representative specimens are indicated in table 1.

Remarks.—This species is one of the most distinctive, easily

identified, and common Morrow crinoids. As is indicated by the specific name and by Mather's discussion, there was doubt as to assignment of this form to *Delocrinus*. Mather's uncertainty,

TABLE I

Measurements of Paradelocrinus dubius *(Mather)*

	SPECIMEN						
	a	b	c	d	e	f	g
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
Maximum diameter of calyx	15.8	16.7	20.0	21.0	16.0	17.5	25.5
Diameter of calyx at top of RR	14.3	16.5	17.0	19.0	15.8	?	20.0
Height of calyx	5.8	6.6	8.2	8.6	5.4	6.8	10.8
Depth of basal concavity	2.8	4.2	4.7	7.1	4.4	6.2	7.0
Width of body cavity	7.6	10.0	11.0	9.5	8.7		10.5
Diameter of stem impression	2.5	2.2	2.5	2.4	2.5	1.9	2.5
Infrabasals, maximum width		1.5	1.6	1.9	1.5	1.9	1.9
maximum height		2.1	2.5	2.7	2.1	3.3	3.2
Basals, maximum width, ant. BB	6.5	8.5	9.5	10.2	7.2	7.4	11.3
maximum width, pB	6.0	6.0	7.5		6.6	6.6	10.0
height, ant. BB	7.1	10.0	10.1	11.5	8.0	9.9	15.2
height, pB	7.5	9.0	9.7		7.5	9.1	14.0
length ant. B-R suture	6.2	6.9	7.1	7.2	6.0	6.3	9.8
length pB-R suture	6.3	5.2	5.5		5.2	5.3	8.8
length inter-BB suture	4.4	8.1	7.5	8.8	6.3	5.6	9.0
Radials, maximum width	9.5	11.1	12.8	12.9	10.2	10.0	16.0
width, upper margin	8.6	11.0	11.8	12.2	9.8	10.0	12.4
maximum height	6.3	5.6	8.5	7.4	6.3	5.5	13.5
length inter-RR suture	3.1	3.1	5.7	4.7	3.9	3.1	5.7

a—Holotype, Brentwood limestone, near Fayetteville, Ark. Chicago Univ. Walker Museum, 16661.

b, c—Metatypes, Morrow formation, near Fort Gibson, Okla. Chicago Univ. Walker Museum, 16662.

d, f—Hypotypes, Brentwood limestone, Keough quarry, north of Fort Gibson, Okla., Kansas Univ., nos. 45191, 45191*a*; collected by C. L. Foster.

e—Hypotype from same locality and horizon as d, f, Kansas Univ., no. 45191*b*; collected by R. Rose.

g—Hypotype from Brentwood limestone, one-half mile east of Woolsey, Ark., Kansas Univ. no. 45223; collected by R. C. Moore.

he states, was due to the fact that the anal plate of the holotype fails by 0.3 mm. to touch the pB even though the lower part of anal x is below the upper border of the RR. Curiously enough, Mather makes no mention of the fact that of the several speci-

mens in his possession at the time of preparing his description, (all of which have been placed at our disposal for study) only the holotype shows presence of an anal plate in the dorsal cup. These other specimens, like those in our own collection, indicate definitely the location of the anal plate but it is in each case excluded from the dorsal cup. Examination of more than 800 specimens of *Delocrinus* and *Erisocrinus* in our possession indicates that form of the cup alone is a reliable basis for separation of these genera. The tendency towards reduction in size of the anal x and its upward migration out of the dorsal cup are features to be expected in *Delocrinus*, just as they are evident in other genera of the Poteriocrinitidae. In *Paradelocrinus* the absence of anal x from the dorsal cup is the rule, rather than the exception.

Occurrence.—Brentwood limestone, Morrow subseries, Pennsylvanian (Upper Carboniferous); near Fayetteville and Brentwood, Ark., and Fort Gibson, Okla.

Types.—Holotype, Chicago Univ. Walker Museum 16661, "Brentwood limestone, near Fayetteville, Ark." (probably from Mather's Loc. 134, cen. sec. 10, T. 16 N., R. 30 W., near northeast edge of Fayetteville, where this species is very common). Metatypes, Chicago Univ. Walker Museum 16662 (4 specimens) "Morrow formation, near Fort Gibson, Okla." Hypotypes, Kansas Univ., nos. 45251. 45251*a-g*; Brentwood limestone, Fayetteville, Ark. (Mather's Loc. 134, noted above); Kansas Univ., nos. 45223, 45223*a-f*, Brentwood limestone, on U. S. Highway 71 and about 1.5 miles northeast of Woolsey, Ark.; Kansas Univ., nos. 45191, 45191 *a-c*, Brentwood limestone, Keough quarry, 2 miles north of Fort Gibson, Okla.

Paradelocrinus? simus Moore and Plummer, n. sp.

Plate XVI, figures 7*a-l*

Crinoid plate, genus and species?, MATHER, 1915, Denison Univ. Sci. Lab. Bull., vol. 18, p. 109, pl. 2, figs. 3, 3a, Brentwood limestone, northwestern Arkansas.

Observed by Mather, and included in our collections from the Morrow beds both of northwestern Arkansas and northeastern

Oklahoma, are peculiar primibrachs that bear a very blunt-nosed, sharply truncated spine. In some cases these spinous brachials are surprisingly large and massive. Mather illustrated a fairly typical example that is slightly large than average size. Extensive observation of Pennsylvanian crinoid material from the Mid-Continent region indicates that these plates may be considered as characteristic of Morrow beds, for they appear to occur at no other horizons and some of them may be found by search at almost any Brentwood limestone exposure; accordingly they may be considered as index fossils, despite incomplete knowledge of the crinoid to which they belong.

Spines nearly circular in cross section, but tending to subtriangular, the dorsal or lower surface being flattened and the ventral or upper side medially elevated; moderately constricted near facets and expanding distally, although small, presumably young examples have nearly straight sides; distal extremity squarely truncated or slightly convex, a few examples, however, appearing concave. Facet for articulation with radial inclined at an angle of about 45° to axis of spine, meeting at a bevel edge the nearly horizontal facets for articulation with IIBr; each of the three facets on a spine shows a strong transverse ridge, a very narrow external ligament area with deep well marked ligament pit, and a broad internal ligament area with large subtriangular muscular fossae and shallow inter-articular ligament fossae, inter-muscular notch moderately narrow and deep; ridge between IIBr facets elevated and thickest in medial part.

Measurements of holotype, length of spine beyond radial facet 10 mm., beyond extremity of IIBr facets 6 mm., total length including facets 12.5 mm., diameter at distal extremity 8 mm. in dorso-ventral plane and 9 mm. horizontally. The largest observed specimen, paratype no. 451913*a*, has a total length of 21 mm., diameter of constricted zone near facets 12 mm., diameter of distal extremity 15 mm. in vertical plane, 17 mm. horizontally.

Surface of all well-preserved examples marked by fine close-spaced ridges that trend parallel to axis of spine; they are slightly irregular and show coalescence and implantation so as to resemble somewhat the skin markings of the human palm.

Remarks.—This rather remarkable type of spine is referred tentatively to *Paradelocrinus* because of the supposition that it belongs to *P. dubius*. The character of the ornamentation agrees, but this is insufficient evidence to make inferences concerning relationships by any means certain. The fact that these spines are fairly common suggests that the cup to which they belong should be found in a collection such as ours. *P. dubius* is the only known Morrow species of sufficient size and strength to permit serious consideration in this connection; yet even the largest observed example of *P. dubius* is much too small to have carried the ponderous spine classed as paratype 451913*a*.

Occurrence.—Brentwood limestone, Morrow subseries, Pennsylvanian (Upper Carboniferous); near Fort Gibson, Okla., and near Fayetteville and Brentwood, Ark.

Types.—Kansas Univ., holotype, no. 451913, and paratypes, nos. 451913*a-z*, *a'-e'*, from Loc. 4519; paratypes, nos. 45226, 45226*a-h*, from Loc. 4522.

Genus AESIOCRINUS Miller and Gurley, 1890

The dorsal cup of species belonging to this genus is bowl-shaped, the arrangement of its plates corresponding to that in *Delocrinus* or *Graphiocrinus*. There is no funnel-shaped basal concavity, as in *Delocrinus*, and possession of a strong anal sac and a pentagonal stem distinguishes *Aesiocrinus* from both *Delocrinus* and *Graphiocrinus*. Trautschold's genus *Phialocrinus*, (1879) is a homonym of *Phialocrinus* Eichwald (1856), and invalid as applied to Carboniferous crinoids.

Genotype, *Aesiocrinus magnificus* Miller and Gurley

Occurrence.—Upper Carboniferous, North America; top of Lower Carboniferous, Scotland.

Aesiocrinus sp.

Plate XIV, figure 3

A fragment of an anal sac occurs in our material from near Fort Gibson, Okla. It shows typical characters of *Aesiocrinus* with 4 or 5 vertical series of subhexagonal plates, with slit-like

pores between the plates of adjacent vertical rows. Each of the plates carries one or two distinct but short spines. The fragment, which is 20 mm. long, appears slightly crushed. It is comparable in size to the sac of *A. magnificus*.

Occurrence.—Brentwood limestone, Morrow subseries, Pennsylvanian (Upper Carboniferous); Loc. 4519, Keough quarry, north of Fort Gibson, Okla.

Figured specimen.—Kansas Univ., no. 451924.

Genus STUARTWELLERCRINUS Moore and Plummer, n. gen.

Reasons for establishment of this genus are given in discussion of *Cibolocrinus* and the chief distinguishing features are given there. For clearness of treatment, a separate heading and brief diagnosis are entered at this point.

Calyx low, turbinate to conical, dicyclic; IBB clearly visible from the side, stem impression typically crateriform. IBB 3, position of small IB variable in different species but generally in anterior, left posterior or right posterior radius. BB 5, pB typically larger than others, and except in a few forms showing marked upward migration of anal x, truncated distally where it is in contact with anal x. RR 5, bearing broad articular facets that project inward so as to constrict aperture to body cavity, muscle area centrally depressed, borders near inter-radial sutures more or less distinctly elevated. Anal x is typically present, separating the posterior RR and resting on pB; in some cases anal x is pressed entirely out of the dorsal cup. Arms unknown.

Genotype, *Cibolocrinus turbinatus* Weller, from Cibolo limestone, Upper Permian, Presidio County, Texas. The syntypes of this species are Chicago Univ. Walker Museum no. 13371.

Remarks.—Other species that are referred to *Stuartwellercrinus* are *Cibolocrinus texanus* Weller and *C. symmetricus* Weller from the upper Permian of western Texas, and *C. minimus* Wanner, *C. propinquus* Wanner and *C. jonkeri* Wanner, from the Permian of Timor. Wanner (1923, p. 253) has concluded that *Stuartwellercrinus symmetricus* is a synonym of *S. turbinatus*, basing opinion doubtless on the none-too-clear figures published by

Weller and on the judgement that the presence or absence of anal x below the summit of the RR is not a feature of specific importance. With Wanner's conclusion concerning lack of special significance of anal x in this case we are entirely in agreement, but examination of Weller's types disposes quickly of the notion that the two species mentioned are synonymous. *S. symmetricus* is unquestionably a valid species, separated from *S. turbinatus* not only by difference in habit of anal x, but by dissimilarity in contour of the calyx and shape of RR.

This genus is named in honor of the late Prof. Stuart Weller, of the University of Chicago, to whom both of the writers of this paper owe an abiding interest in paleontology, and especially in Carboniferous invertebrates.

Occurrence.—Upper Permian; western Texas, and Timor, Dutch East Indies.

Genus PARAPLASOCRINUS Moore and Plummer, n. gen.

This genus is proposed to receive the species described as *Cibolocrinus transitorius* by Wanner (1916, p. 208; 1923, p. 254).

Calyx low basin-shaped, with more or less deeply impressed central area at base, involving not only IBB, which are invisible from the side, but proximal portion of BB; plates smooth to somewhat bulbous. Otherwise, the characters of this genus correspond to those of *Stuartwellercrinus*, but the small IB tends to occur most commonly in the right posterior radius.

Genotype, and only described species, *Cibolocrinus transitorius* Wanner, from Upper Permian beds of Timor, Dutch East Indies.

Remarks.—Judging from Wanner's figures of specimens that have been referred by him to *C. transitorius*, it seems doubtful that all are really conspecific. It is reasonable to accept his conclusions as to variation in the size and position of anal x in this assemblage, but it seems to us very possible that there are now included under one name a number of generically related but specifically distinct forms. The specimen illustrated by Wanner in his 1923 paper on plate 18, fig. 1, lacks the depressed base that is so well developed in other examples identified as belonging to *C. transitorius*, and it appears that this specimen does not belong to *Paraplasocrinus*. Probably, then, this new genus will be

found to number several species besides that based on the holotype of *C. transitorius* (Wanner, 1916, pl. 8, figs. 11*a-c*). The name *Paraplasocrinus* is derived from παραπλαζω, lead astray.

Occurrence.—Permian; Timor, Dutch East Indies.

Genus DIPHUICRINUS Moore and Plummer, n. gen.

Calyx low basin-shaped, with base sharply and strongly depressed. IBB 3, at bottom of basal concavity of cup, mostly or entirely covered by stem attachment; the small IB in the genotype species is in the left anterior radius. BB 5, nearly equal, proximal parts forming sides of basal concavity of cup, distal parts curving upward to about mid-height of outer wall of calyx; pB truncated distally for contact with anal x. RR 5, wider than long; articular facets of moderate width, nearly plane. A single anal plate interrupts circle of RR, resting on pB and rising slightly above summit line of RR. In exterior view of dorsal cup sutures are only slightly impressed; separated plates of the cup show that the faces of sutures are more or less deeply excavated, the depressions carrying cross ridges, very pronounced in some examples, for muscular and ligamentous attachment. Arms and tegmen unknown.

Genotype, *Diphuicrinus croneisi* Moore and Plummer, n. sp., Morrow subseries, Upper Carboniferous, near Fort Gibson, Okla.

Remarks.—The shape of the dorsal cup of *Diphuicrinus* is essentially the same as in *Delocrinus*, but the external ornamentation of strong rounded tubercles, is foreign to the latter genus, resembling rather the common type of decoration seen in *Ethelocrinus*. Because a strongly marked basal concavity of the cup, presence of a single anal plate resting on the truncated tip of pB, and relative thickness of plates are distinctive features of *Delocrinus*, we were disposed at first to regard *Diphuicrinus croneisi* as an unusual representative of *Delocrinus*. In the first two specimens studied, the IBB circlet is unfortunately missing, although the proximal margins of the BB may be seen. A paratype obtained later, however, establishes the fact that there are only 3 IBB, and this is sufficient to show that these crinoids can belong neither to *Delocrinus* nor to a genus related to *Ethelocrinus*.

The remarkable nature of the sutures of calyx plates of *D.*

croneisi is foreign to the Poteriocrinitidae, so far as we can learn, and the evidence as to thickness of muscle and ligament fibers between the plates fits rather with characters of the Flexibilia or Articulata than of the Inadunata. Even a highly developed member of the Flexibilia, such as *Forbesiocrinus* (see Springer, 1920, pls. 23, 24), shows no greater indication of loosely ligamentous union in plates of the dorsal cup than appears here. Yet the appearance of the cup of *Diphuicrinus* is clearly that of an inadunate rather than of a flexible crinoid.

The deep basal concavity in the cup is a character especially foreign to the Flexibilia. It can hardly be supposed that *Diphuicrinus* is related to the Lecanocrinidae or any other established family of Flexibilia, and because it is believed not to belong among poteriocrinids, possibly a new family should be designated to receive it. The presence of 3 IBB is a character of all flexible crinoids, and although, among genera of the Flexibilia, the small IB typically occurs in the right posterior radius, there are rare exceptions. An important matter for consideration is the implication, hardly admissable, that would be carried by assignment of *Diphuicrinus* to a place among the Flexibilia—the derivation of a so-called Flexibilia stock out of an advanced and geologically late-appearing inadunate. The name, *Diphuicrinus* (διφυιος—of two tribes), indicates uncertainty as to relationship among the crinoids.

Diphuicrinus croneisi Moore and Plummer, n. sp.

Plate XIV, figure 6; plate XVI, figures 3a-c, 4a-g, 10; text-figure 37.

Calyx depressed, with comparatively flat base and steeply rounded sides, central part of base sharply and deeply invaginated. Maximum diameter of calyx in plane slightly above mid-height, holotype, 23 mm.; paratype, A (no. 45211*a*), 18 mm.; paratype B (P9267), 29 mm.; height, holotype 8 mm., paratype A, 7 mm., paratype B, 11 mm. Depth of basal depression, holotype, 5.2 mm., paratype A, 4.5 mm., paratype B, 6.5 mm.

IBB 3, forming bottom of basal invagination, mostly covered by stem impression; these plates, only observed in paratype B,

form a high cone on the inside of the cup, the apex of the cone pierced by a 5-rayed canal with petal-like rays radial in position; sutures between plates very obscure but study of crystallographic orientation establishes existence of only 3 plates in this circlet, the small IB in left anterior radius; inside diameter of IBB disk at summit, holotype, 4.5 mm.; paratype A, 3.5 mm.; paratype B, about 3.7 mm.

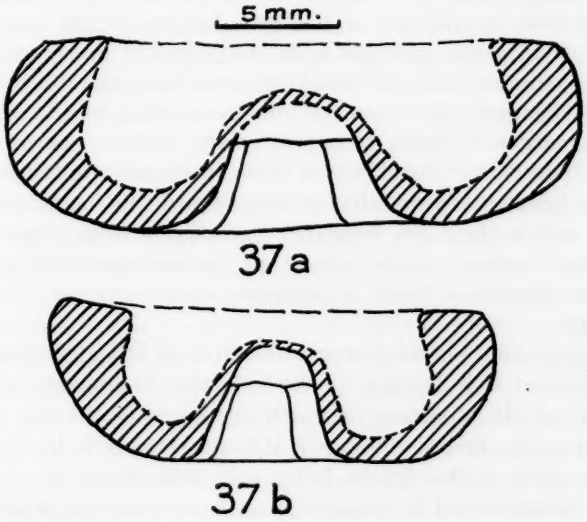


FIG. 37. CROSS-SECTIONS OF THE DORSAL CUP OF *Diphuicrinus croneisi*, N. SP. *a*, holotype; *b*, paratype

BB 5, nearly equal, length measured along curvature slightly greater than maximum width, pB truncated distally for contact with anal x and a little shorter and narrower than other BB; about 3 mm. of the proximal portion of each plate lies nearly parallel to the dorsoventral axis of the calyx that is, vertical—beyond which the median part is flexed very sharply into a nearly horizontal plane, the distal part curving upward gently to a point near the mid-height of the calyx. Measurements of raB, holotype, length, 8.8 mm., width, 7 mm.; paratype A, length,

7.7 mm., width, 6.0 mm.; pB in holotype, length, 6.6 mm., width, 5.2 mm., paratype A, length, 6.5 mm., width, 5.0 mm.

RR 5, maximum width near mid-length, measuring about 10.0 mm. in holotype, length along curvature 7.0 mm.; rather evenly convex in longitudinal profile, the proximal part curving downward and inward only slightly more than the distal part curves upward and inward; inter-RR sutures nearly vertical. Articular facets nearly plane and almost exactly horizontal; they are separated from lateral face of RR by a line and slight angulation that curves gently outward from the angles at upper margin of RR; maximum width of dorsal ligament fossa about 1.6 mm., a narrow ligament pit, about 3.0 mm. long, being seen at center of inner margin of fossa; transverse ridge narrow, sharp-crested, finely denticulate; distal part of facet, inside the transverse ridge, shows ligament fossae that widen toward the median line of plate where they are separated by a faint ridge, and evenly rounded, convex muscle areas that become most distinct near lateral margins of facet; a depressed area occurs at interradial sutures.

A single anal plate interrupts the circle of RR at the posterior interradius; it is lacking in the holotype, the suture at distal margin of pB indicating its width at base to be 2.8 mm. and its height to the line of summit of RR can be seen to be about 3.5 mm., width at this height being very little more than at base. Anal x is preserved in the paratypes about two-fifths of its length projecting above the summit of the RR.

Surface covered by coarse rounded tubercles that are irregularly disposed, about 12 to 18 tubercles occurring on each R and B; these are all somewhat worn in the types but they are nevertheless prominent, some of the most nearly perfect nodes rising about 0.6 mm. above the general surface.

In addition to three calices on which the foregoing description is based, we have seven separated radial plates and one basal plate, that appear evidently to belong to *D. croneisi*. One of the radials is from the same locality as the holotype and paratype A; the other plates come from Keough quarry, north of Fort Gibson, Okla. The separated plates carry the coarse rounded tubercles of this species and correspond closely in shape. They

are very readily separated from the numerous plates of *Ethelocrinus* in our collection, even though the surface ornamentation makes them appear at first glance to belong here; the distinctive difference of these from the *Ethelocrinus* plates is seen in their different shape, very much greater relative thickness, and in the peculiarly deep-etched sutures. The depth of the sutural ligament fossae and their transversely arranged cross ridges, are developed with varying strength, for some of the plates have much less deeply marked depressions than in the forms illustrated. The separated plates show better preservation than the calices, and it may be noted that the tubercles of the former are slightly larger and more widely spaced. The form and size of the separated plates are exactly like those of corresponding plates of the calices.

Remarks.—The general appearance of this interesting species is so like that of a somewhat flattened *Ethelocrinus* that one is surprised, on examination, to find no RA. Further study indicates that this crinoid is distinct in various features from any known form. The structure of the calyx, including especially the deep ligament fossae of the suture faces, is regarded as a generic character; the precise form, approximate size and the nature of surface ornamentation are specific characters.

Occurrence.—Brentwood limestone, Morrow subseries, Pennsylvanian (Upper Carboniferous); Loc. 4521, Braggs Mountain, along highway about 3 miles southeast of Fort Gibson, Okla. Collected by R. C. Moore; Loc. 4522a, road cut on U. S. Highway 71, about 0.2 mile north of iron bridge at Woolsey, Ark., collected by F. B. Plummer.

Types—Kansas Univ., holotype, no. 45211; paratype A, 45211*a*; (both, Loc. 4521); paratype B., Univ. Texas, Plummer Coll., no. P9267 (loc. 4522a); paratypes (separated plates), nos. 451910, *a*, *b*, from Brentwood limestone, Keough quarry, sec. 36, T. 16 N., R. 19 E., Okla.

CRINOIDS OF UNCERTAIN RELATIONS

Genus STEREOBRACHICRINUS Mather, 1915.

This genus is based on specimens of arms, no other parts of the crinoid being known. These arms are distinguished by the fusion

of the quadrangular uniserial segments into an inflexible nearly straight spine-like structure. That these fossils are rightly interpreted as crinoid arms is shown by traces of the segments, and, more significantly, by the presence of a very narrow ambulacral groove on the somewhat flattened inner side.

Genotype *Stereobrachicrinus pustullosus* Mather

Occurrence.—Brentwood limestone, Morrow subseries, Pennsylvanian (Upper Carboniferous); Arkansas and Oklahoma.

Stereobrachicrinus pustullosus Mather

Plate XVI, figures 8a, b

A typical example of this interesting form is given, supplementing that published by Mather. We can add no information as to the genus or species except to note that complete examples of the arms are rather longer than indicated by Mather, measuring 40.0 and exceptionally nearly 50.0 mm. in length, instead of only 25.0 or 30.0 mm. Also, it may be observed that these remains are very common and much more widely distributed than observed by Mather. They may be found at almost any outcrop of the Brentwood limestone in northwestern Arkansas, as well as in territory near Fort Gibson, Okla., from which the types were obtained. This species may be considered as one of the good guide fossils of the Morrow beds.

Remarks.—The general shape and the fused condition of the segments of the arms here considered are strikingly suggestive of characters shown by the arms of *Allagecrinus*. Kirk (1936) has recently described and illustrated a Pennsylvanian species of *Allagecrinus* that is represented by a number of examples with arms attached to the dorsal cup, and we are fortunate in having also several similar specimens. These are unique in that no form of this genus has been known previously with attached arms. In spite of similarity between *Stereobrachicrinus* and the *Allagecrinus* arms, it hardly seems possible that the two are the same, for all known species of *Allagecrinus* are very minute,—almost microscopic,—whereas the cup of *Stereobrachicrinus* must be 10 mm. or more in diameter. In other words, if *S. pustullosus* is really an *Allagecrinus*, it is at least four or five times larger

than other known species of this genus. Until the cup that corresponds to *Stereobrachicrinus* is found,—and in view of the abundance of arms the lack of such discovery is very surprising,—it seems best to let Mather's designation of this crinoid stand.

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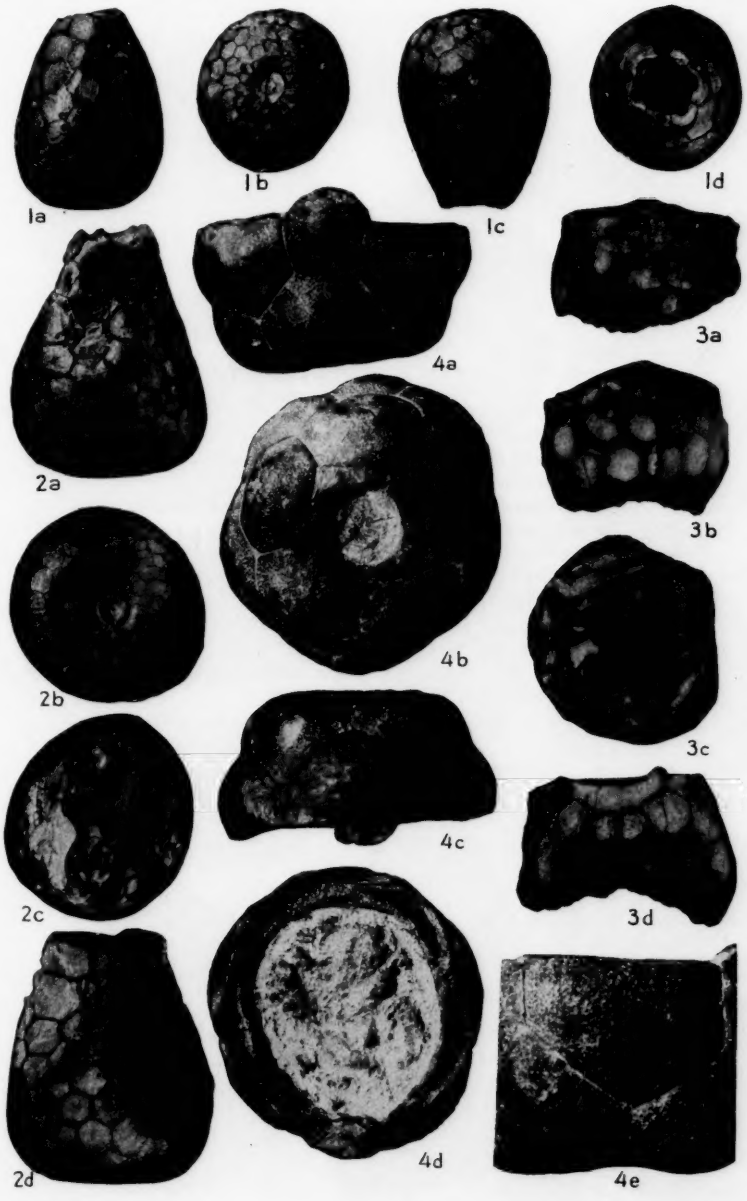
EXPLANATION OF PLATE XII

Figs. 1a–d, 2a–d. *Acrocrinus pirum* Moore and Plummer, n. sp., ×2. 1a–d, posterior, dorsal, anterior and ventral views of paratype (Kansas Univ., no. 45192a). 2a–d, posterior, dorsal, ventral, and right posterior views of holotype. Brentwood limestone, Loc. 4519, north of Fort Gibson, Okla.

Figs. 3a–d. *Acrocrinus brentwoodensis* Moore and Plummer, n. sp., ×2. Posterior, anterior, ventral, and right anterior views of holotype. Brentwood limestone, Loc. 4526, near Woolsey, Ark.

Figs. 4a–e. *Cibolocrinus tumidus* Moore and Plummer, n. sp., ×2. Posterior, dorsal, anterior, ventral, and enlarged detail views of holotype. Brentwood limestone, Loc. 4519, north of Fort Gibson, Okla.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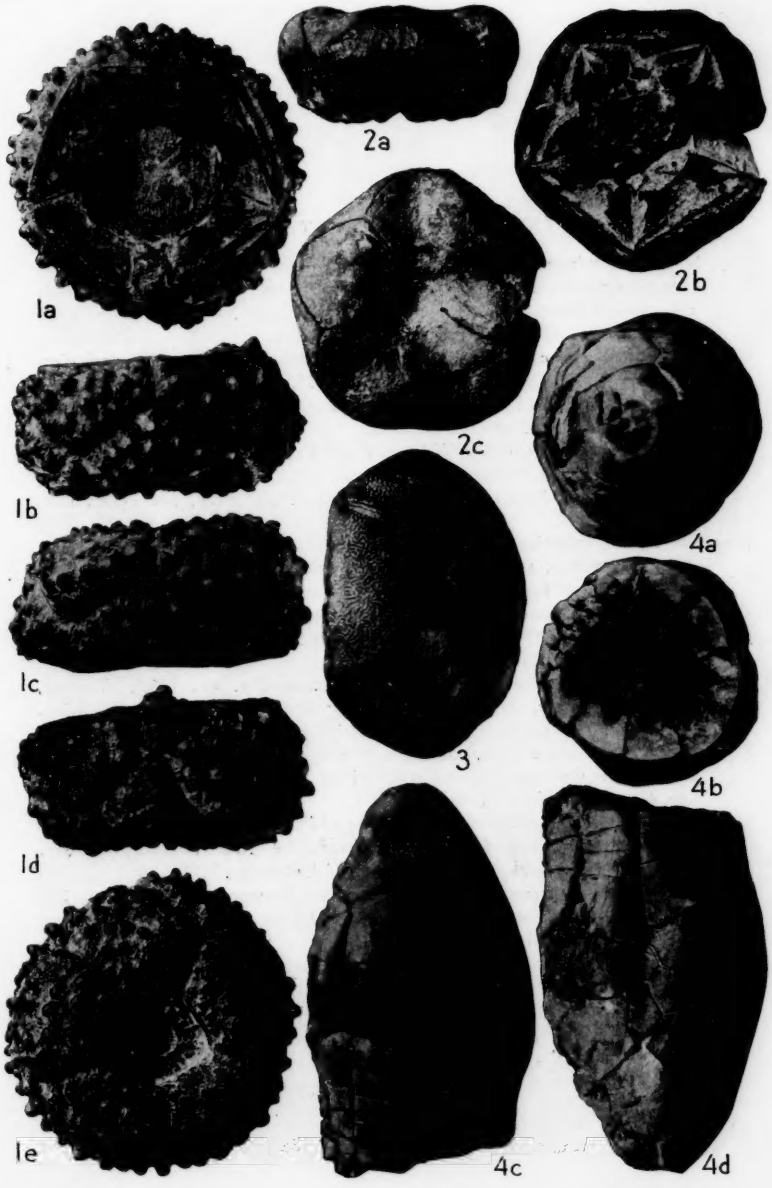
EXPLANATION OF PLATE XIII

Figs. 1a–e. *Ethelocrinus oklahomensis* Moore and Plummer, n. sp., ×1.5. Ventral, left side, anterior, posterior, and dorsal view of holotype. Brentwood limestone, "north of Muskogee, Okla." (probably same as our Loc. 4519). Holotype in collection of University of Oklahoma.

Figs. 2a–c. *Paradelocrinus dubius* (Mather), ×1.5. Anterior, ventral, and dorsal views of large hypotype (Kansas Univ., no. 45223). Brentwood limestone, Loc. 4522, near Woolsey, Ark.; occurs widely.

Fig. 3. *Delocrinus matheri* Moore and Plummer, n. sp., ×3. Oblique view to show ornamentation; holotype. Brentwood limestone, north of Fort Gibson, Okla.

Fig. 4a–d. *Morrowcrinus fosteri* Moore and Plummer, n. gen, n. sp., ×2. Dorsal, ventral, anterior, and posterior views of crown; holotype. Brentwood limestone, Loc. 4519, north of Fort Gibson, Okla.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EXPLANATION OF PLATE XIV

Figs. 1a–f. *Plaxocrinus strigosus* Moore and Plummer, n. gen., n. sp., ×2. 1a–c, Dorsal, anterior, and ventral views of holotype. 1d–f, Anterior, dorsal, and ventral views of paratype (Kansas Univ., no. 45203a). Brentwood limestone, Loc. 4520, north of Fort Gibson, Okla.

Fig. 2. *Agassizocrinus caliculus* Moore and Plummer, n. sp., ×3. Ventral view of holotype. Brentwood limestone, Loc. 4522, near Woolsey, Ark.

Fig. 3. *Aesiocrinus* sp., ×1.25. Portion of the anal tube. Brentwood limestone, Loc. 4519, north of Fort Gibson, Okla.

Figs. 4a–e. *Paradelocrinus aequabilis* Moore and Plummer, n. gen., n. sp., ×2.5. 4a–d, Anterior, posterior, ventral, and dorsal views of holotype. 4e, Dorsal view of holotype, ×1.2. Brentwood limestone, Loc. 4522, near Woolsey, Ark.

Figs. 5a–c. *Perimestocrinus teneris* Moore and Plummer, n. gen., n. sp., ×2.5. Posterior, dorsal, and anterior views of holotype. Brentwood limestone, Loc. 4522, near Woolsey, Ark.

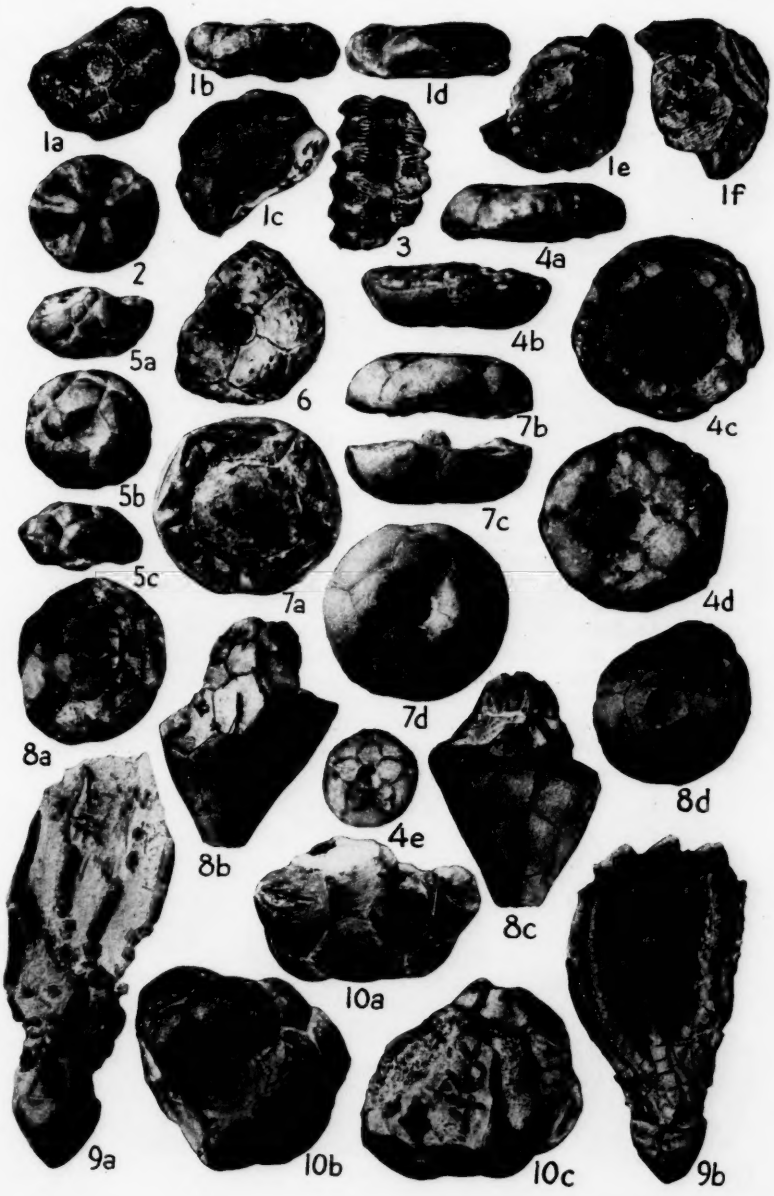
Fig. 6. *Diphuicrinus croneisi* Moore and Plummer, n. gen., n. sp., ×1.5. Dorsal view of paratype (Kansas Univ., no. 45211a.) Brentwood limestone, Loc. 4521, near Fort Gibson, Okla.

Figs. 7a–d. *Delocrinus matheri* Moore and Plummer, n. sp., ×2.5. Ventral, anterior, posterior, and dorsal views of paratype (Kansas Univ., no. 45196). Brentwood limestone, Loc. 4519, north of Fort Gibson, Okla.

Figs. 8a–d. *Hydriocrinus? rosei* Moore and Plummer, n. sp., ×1.5. Ventral, posterior, anterior, and dorsal views of holotype. ?Brentwood limestone, Loc. 4519, north of Fort Gibson, Okla.

Figs. 9a, b. *Scytalocrinus sansabensis* Moore and Plummer, n. sp., ×2.5. Views of two syntypes, both from near anterior side. Marble Falls limestone, southeast of San Saba, Texas. Types, Univ. Chicago, 31721.

Figs. 10a–c. *Perimestocrinus pumilis* Moore and Plummer, n. gen., n. sp., ×2. Posterior, dorsal, and ventral view of holotype. Brentwood limestone, Loc. 4521, southeast of Fort Gibson, Okla.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EXPLANATION OF PLATE XV

(All figures on this Plate, ×1.3)

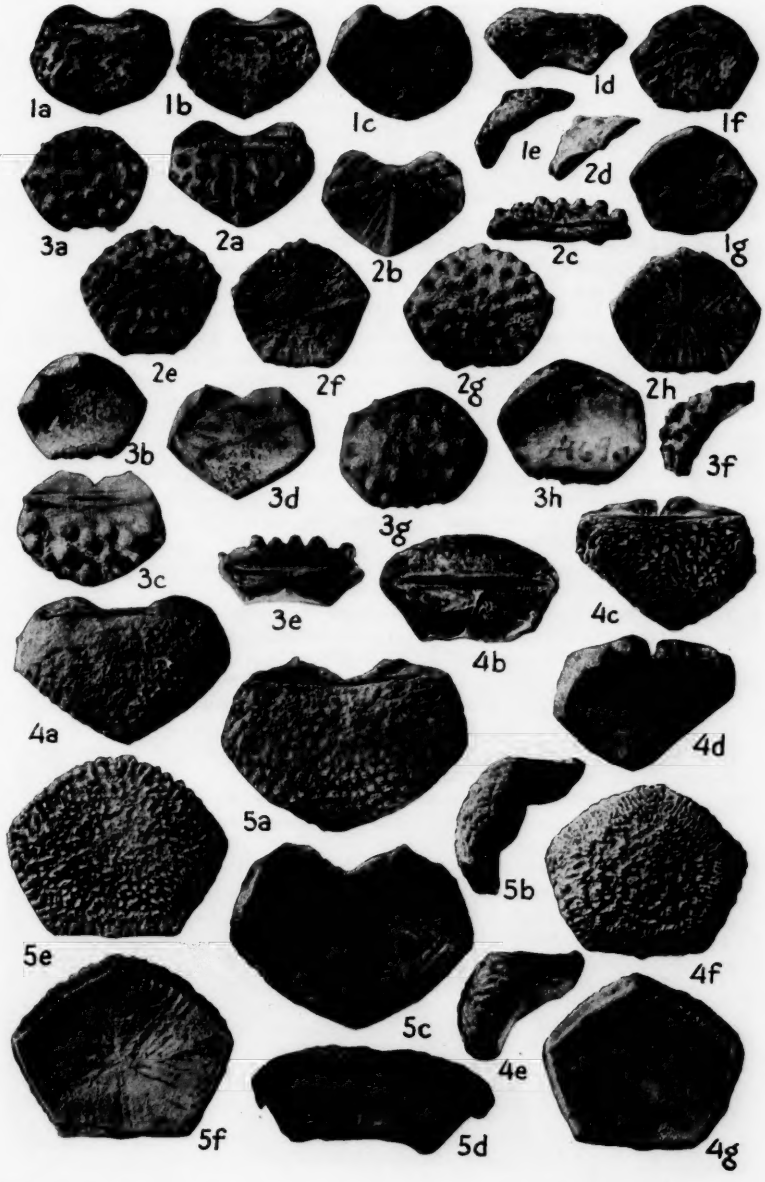
Figs. 1a–g. *Ethelocrinus subsinuatus* Moore and Plummer, n. sp. 1a, Radial (paratype, K.U. no. 451911d). 1b–e, Holotype, radial. 1f, g, Basal (paratype, K.U. no. 451911g). Brentwood limestone, loc. 4519, north of Fort Gibson, Okla.

Figs. 2a–h. *Ethelocrinus costalis* Moore and Plummer, n. sp. 2a–d, Radial (paratype, K.U. no. 451912f'). 2e, f, Holotype, basal. 2g, h, Basal (paratype, K.U. no. 451912a). Brentwood limestone, Loc. 4519, north of Fort Gibson, Okla.

Figs. 3a–h. *Ethelocrinus oklahomensis* Moore and Plummer, n. sp. 3a, b, Basal (paratype, K.U. no. 451914g). 3c–f, Radial (paratype, K. U. no. 451914a). 3g, h, Basal (paratype, K.U. no. 451914h). Brentwood limestone, Loc. 4519, north of Fort Gibson, Okla.

Figs. 4a-g. *Ethelocrinus hispidus* Moore and Plummer, n. sp. 4a, Radial (paratype, K.U. no. 45199c). 4b-e, Holotype, radial. 4f, g, Basal (paratype, K.U. no. 45199e). Brentwood limestone, Loc. 4519, north of Fort Gibson, Okla.

Figs. 5a–f. *Ethelocrinus papulosus* Moore and Plummer, n. sp. 5a–d, Holotype, radial. 5e, f, Basal (paratype, K.U. no. 45198b). Brentwood limestone, Loc. 4519, north of Fort Gibson, Okla.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EXPLANATION OF PLATE XVI

Figs. 1a–c. *Delocrinus matheri* Moore and Plummer, n. sp., ×2. Posterior, dorsal, and anterior views of holotype. Brentwood limestone, Loc. 4520, north of Fort Gibson, Okla.

Figs. 2a–d. *Cibolocrinus regularis* Moore and Plummer, n. sp., ×2. Posterior, dorsal, ventral (posterior half), and anterior views of holotype. Brentwood limestone, Loc. 4519, north of Fort Gibson, Okla.

Figs. 3a–c, 4a–g, 10. *Diphuicrinus croneisi* Moore and Plummer, n. sp. 3a–c, Anterior, dorsal, and posterior views of holotype, ×1. 4a–d, Radial (paratype, K.U. no. 451910), showing deep ligament pits on suture faces; 4c, view from plate interior, 4d, from lateral edge; ×1.6. 4e, Lower edge of radial (paratype, K.U. no. 451910a), showing ligament pits. 4f, g, Basal (paratype, K.U. no. 451910c), exterior and interior views, latter showing ligament pits along sutures. 10, Ventral view of part of a large paratype, showing fairly well preserved articular facets, ×1.6. (Plummer coll. no. P9267). Brentwood limestone, holotype from Loc. 4521 southeast of Fort Gibson, Okla.; separated plates from Loc. 4519, north of Fort Gibson; paratype P9267, from near Woolsey, Ark.

Fig. 5. *Agassizocrinus magnus* Moore and Plummer, n. sp. Side view of holotype, ×1. Kessler limestone, Hale Mountain, near Morrow, Ark.

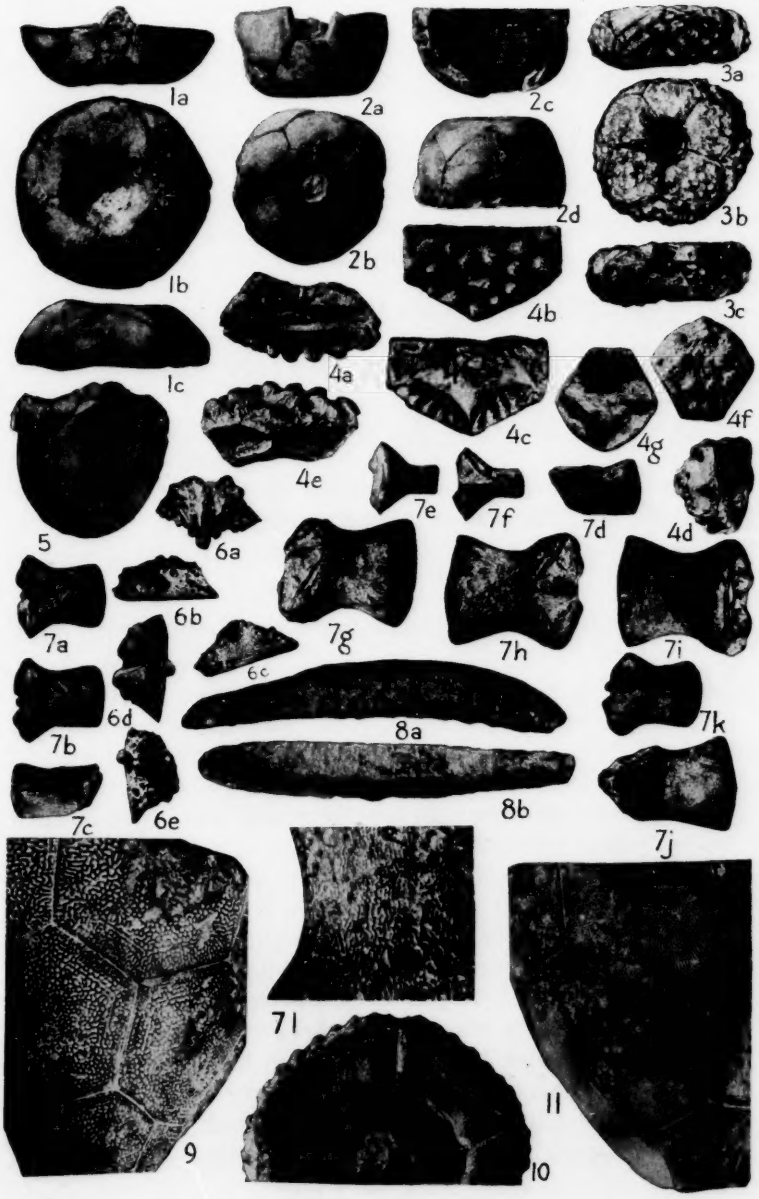
Figs. 6a–e. *Ethelocrinus* sp., cf. *E. oklahomensis* Moore and Plummer. A very well preserved IBr that shows the surface ornamentation of *E. oklahomensis*, ×1. Brentwood limestone, Loc. 4519, north of Fort Gibson, Okla.

Figs. 7a–l. *Paradelocrinus? simus* Moore and Plummer, n. gen., n. sp. 7a–d, k, Holotype, ×1. 7e, f, A small type of primibrach spine (paratype, K.U. no. 451913c). 7g–j, The largest observed specimen (paratype, K.U. no. 451913a). 7l, Part of area near base of spine (paratype 451913a) showing ornamentation, ×3.

Figs. 8a, b. *Stereobrachicrinus pustullosus* Mather, ×1.5. Side, and dorsal (outer) views of a typical specimen, nearly complete. Brentwood limestone, Loc. 4522, near Woolsey, Ark.

Fig. 9. *Hydriocrinus? rosei* Moore and Plummer, n. sp. Part of dorsal cup enlarged to show ornamentation; radial at top of view is the anterior; ×3. ?Brentwood limestone, Loc. 4519, north of Fort Gibson, Okla.

Fig. 11. *Morrowcrinus fosteri* Moore and Plummer, n. gen., n. sp. Part of dorsal cup enlarged to show ornamentation; radial at upper right is the right anterior. Brentwood limestone, Loc. 4519, north of Fort Gibson, Okla.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DENISON SCIENTIFIC ASSOCIATION

Organized April 16, 1887

REPORT OF THE PERMANENT SECRETARY FOR THE YEAR 1936–1937

Officers serving the Association during the college year 1936–1937 were as follows:

W. A. EVERHART, *President*
R. H. HOWE, *Vice-President*
W. C. EBAUGH, *Permanent Secretary and Editor*
CHARLOTTE RICE, *Recording Secretary and Treasurer*
L. E. SMITH, *Librarian*

In accordance with its usual custom the Association met in the Physics Lecture Room, Barney Science Hall, on alternate Tuesday evenings; programs follow.

October 13

THE LIFE CYCLE AND ITS CONTROL. M. E. STICKNEY, Retiring President.

Most living things have their beginnings as single germ cells, pass through a vegetative stage of growth and development to maturity, and thus advance to a reproductive stage in which there are formed other germ cells to initiate the next generation. This round of life, including the vegetative and reproductive stages, is spoken of as the Life Cycle. But what causes the organism to go over from the vegetative to the reproductive phase of its life cycle? Is it something within the organism, or the effect of some environmental factor or factors? In man, maturity is reached normally at from fourteen to eighteen years of age, or—in hot climates—a year or two earlier. It has been discovered, however, that the introduction of certain gland products may cause the appearance of manifestations of maturity at six. In the case of plants it is readily shown that the reproductive stage may be induced almost at will by altering certain environmental factors such as light intensity, length of day, oxygen pressure,

temperature, and amount of moisture present. Organisms, in order to survive in a changing world, must themselves be able to respond to changes in their environment.

October 27

THE GEOLOGY AND GEOGRAPHY OF GASPÉ. GEORGE D. HUBBARD (Professor Emeritus of Geology, Oberlin College).

From a wealth of experience gained through long-continued study of the most eastern part of the Province of Quebec, Canada, there was presented an account of the structure and land features of the country as a background for the development and economic life of its inhabitants. The information was particularly opportune in view of the interest in the Gaspé Peninsula as a tourist center during recent years.

November 10

ASTRONOMY IN MOVING PICTURES. (1) The Casting of the 200-inch "Eye" (2) The Heavens in Motion. FREEMAN D. MILLER.

The pouring and subsequent treatment of the glass for the 18-ton Pyrex disc made at the Corning Glass Works, destined for the 200-inch reflector of the California Institute of Technology's new telescope, were shown. This is said to be the most expensive instrument of research ever constructed.

Reels from the McMath-Hulbert Observatory were used to show changes in the heavenly bodies too slow to be observed by ordinary techniques. Pictures are taken at a very slow rate, and speeded up enormously when projected upon the screen, thus compressing events of several days into a few seconds. As subjects were used sunrise and sunset on the craters of the moon, rotation of the giant planet Jupiter and its moons, and the sun with its spots.

November 24

AN EXPERIMENT WITH FRESHMEN IN MATHEMATICAL ORIENTATION. FORBES B. WILEY.

The emphasis in secondary school mathematics and in the orthodox freshman and sophomore courses in colleges is upon

technique in the manipulation of symbols. The student may become proficient at this and still have but little appreciation of mathematics itself and of the contributions it has made to our civilization. At Denison was tried the experiment of supplying this deficiency by giving to upper-class students an elective course non-technical and cultural in its nature. Other colleges are now following this lead. We are at present asking—and trying to answer—the question "Why not let freshmen know these things?" The traditional division walls between algebra, geometry, trigonometry, analytical geometry and calculus are broken down, human interest phases are emphasized, connections with logic, philosophy, psychology and religion are pointed out, and an attempt is made to integrate the whole course.

December 8

BROWNIAN MOVEMENT. L. E. SMITH.

The study of the Brownian movement—first described by Robert Brown, an English botanist—has provided evidence in direct support of our molecular kinetic hypothesis, has made it possible to determine the number of molecules in a given weight or volume of a substance, and thus compute the masses of molecules themselves. Through much carefully planned and brilliant experimental work on the Brownian movement, doubts as to modern assumptions and methods of procedure have been dispelled.

January 5

REACTION-TIME AS A FACTOR IN DRIVING. BRUCE D. GREENSHIELDS.

An automobile does not become a complete mechanism until the driver has placed himself behind the wheel. It is the driver who sees the curve and turns the steering wheel, and who hears the whistle of the train and slows down. The interval between seeing, hearing, or feeling, and doing something about it, is called "reaction-time". The importance of reaction-time in driving, its measurement and applications were discussed. Is the person who can react most quickly necessarily the best driver? How is reaction-time related to highway capacity?

A movie on safety, called "Saving Seconds", was used to illustrate the conclusions drawn.

February 9

A GERMAN STUDY OF BODY FORM AND ATHLETIC ACHIEVEMENT. WALTER J. LIVINGSTON.

Results of measurements of body form of 3000 Munich students ranging from ten to twenty years of age, athletic achievements or tests on these same students, and the correlative dependence of the latter upon the former, were discussed. In illustration of the best achievements in formal competition moving pictures of the recent Olympics held in Berlin, Germany, were shown. The "will to win" ranked high among the factors considered.

February 23

APTITUDE AND ATTAINMENT IN CHEMISTRY. W. C. EBAUGH.

Will a prospective student of chemistry rate high in his course and like his subject, or be always among the failures and detest the very thought of chemistry? Can a final grade in elementary chemistry be determined before a student has had a day's work in lecture room or laboratory? To what extent can square and round pegs be classified or sorted out? To help answer such questions Chemistry Aptitude Tests, prepared by experts in science and education, have been used with students entering Denison's Department of Chemistry. The correlation between scores on such tests and grades finally assigned students for the year's work is high, but with enough exceptions to forbid using the results of such aptitude tests as an absolute measure of potential ability or success in chemistry. Were the lowest ten or fifteen percent of students to be refused permission to continue their course in chemistry it would really be doing them a favor, but almost invariably some members of this group are able to finish the course with better grades than their first test would indicate; as a result it is not deemed wise to use the diagnostic test, good though it may be, as a means for excluding prospective students from the course. The forms of tests used, results ac-

cumulated over a number of years, and interpretations of seeming inconsistencies, were shown.

March 9

EARLY DEVELOPMENT: CHILD AND APE. CHARLOTTE RICE.

For some time moving pictures of men and animals have been used to define clearly stages of motor development which had previously been assumed. Many surprises have come out of this type of study, and many theories have had to be revised as a result of it. Other theories of the sequences of developmental progress have evolved, however, and it is these theories and the illustration of them in actual activity that the films shown portrayed. Topics were (a) manipulation; (b) locomotion; (c) comparative motor development of ape and child.

March 23

ANIMAL PARASITES AND HUMAN DISEASE. G. D. MORGAN.

The life histories of some common human parasites were traced, their mode of entrance into the body shown, and the effects upon the system discussed. Thus trypanosomes and sleeping sickness, blood flukes and circulatory disturbances, hookworms and systemic debility, nematodes and lymphatic disorders, trichinae and pork infection, were used to illustrate both the ways in which diseases are transmitted and the methods of control best adapted for combatting them.

April 27

THE ART OF ORGAN BUILDING. BRAYTON STARK.

The early history of the organ was outlined, and the evolution of the organ action from primitive times to the present day was discussed and demonstrated by actual models. The art of pipe making and voicing was treated fully; metal, wood, and reed pipes were demonstrated and the reasons for their tonal qualities shown. The tremendous rôle played by higher harmonics in developing true organ tones was emphasized, and a discussion of the recently developed so-called electronic organs brought out

the wide divergence between this type of instrument and true organs in both sound production and tonal quality.

May 11

FROM WIRELESS TO RADIO. R. H. Howe.

The year 1937 marks the thirtieth anniversary of the invention of the 3-element vacuum tube by Lee de Forest; and it was the invention of this tube that marked the beginning of the phenomenal growth of our present radio industry. A brief discussion of the more important developments contributing to the success of the present systems of radio transmission and reception was presented. The increasing use of crystals such as quartz and Rochelle salts to stabilize wave lengths in modern instruments of high precision—both transmitters and receivers—was mentioned, and demonstrated experimentally. Future trends were outlined briefly.

Since April 16, 1937, marked the semi-centennial of the founding of the Denison Scientific Association, appropriate exercises were planned to commemorate this event. On the above date a special assembly of faculty, students and friends of Denison University was held in Swasey Chapel, and the address of the day was given by Dr. Carey G. Croneis (D. U., '22), now Professor of Paleontology at the University of Chicago; his topic was "Science and the College".

In order that alumni and others interested might also have an opportunity to share in the celebration of the semi-centennial, a symposium was arranged for the Saturday of Commencement Week, with a program as follows:

DENISON UNIVERSITY

The Annual Commencement

of

Nineteen Hundred Thirty-Seven

Semi-centennial Celebration of the Founding of the Denison Scientific Association

---

SATURDAY, JUNE TWELFTH, AT 2:30 P.M.
RECITAL HALL

General Theme—Contributions of Science to Human Welfare

Guest Speakers:

HERBERT GROVE DORSEY

C. JUDSON HERRICK

WILLIAM E. WICKENDEN

Open Discussion

Dr. Herbert Grove Dorsey (D. U., '97), now Principal Electrical Engineer, U. S. Coast and Geodetic Survey, spoke on "The Application of Physics to Modern Hydrographic Surveying" and traced the development of sounding methods from ancient times to the present, culminating in the Dorsey Fathometer. This instrument is now standard equipment on vessels the world over, and is required by law on all United States boats of 5500 tons register or over. The lecture was illustrated profusely.

Dr. C. Judson Herrick (D. U., '91), now Professor Emeritus of Neurology at the University of Chicago, chose as his topic "Our Endowment" and developed the idea that intellectual and spiritual endowments are far more valuable than those merely physical or financial in their nature. As a charter member of the Denison Scientific Association—he was a student in Doane Academy when his elder brother, Clarence Luther Herrick, organized the Association—with a long connection with Denison University as student, teacher and alumnus, Dr. Herrick was the ideal person to speak authoritatively upon the relation of the College to Science.

Dr. William E. Wickenden (D. U., '04), now President of the Case School of Applied Science, contrasted man's condition before the modern scientific era with what he enjoys now, and so entitled his address "Science—Man's Liberator." His conclusion follows:

> It is not only a happy circumstance, but a fact of deep significance, that science has flourished so fruitfully these last fifty years in this institution calling itself "a Christian College of Liberal Arts." Over much of the world of today the liberal spirit suffers violence. In the dark years before the re-birth of learning in Europe the monasteries rendered an unforgetable service to civilization by keeping the lamp of knowledge alight. In our day the preservation of the liberal spirit in the college and university may prove to be a service of equal significance. So long as the company of scholars unites in good will and generous collaboration—the scientist, seeking to sift fact from falsehood; the humanist, seeking the golden mean between extremes of folly; and the man of religion, striving to bridge the gap between common sense and saving wisdom through spiritual insight—the liberal spirit will endure!

Anticipating the commemoration of the semi-centennial of the founding of the JOURNAL OF THE SCIENTIFIC LABORATORIES and the DENISON SCIENTIFIC ASSOCIATION, there appeared in

this JOURNAL an article by the late Aug. F. Foerste, who was for more than fifty years a member of the Association and a contributor to its publications, entitled "The Earlier History of the BULLETIN OF THE SCIENTIFIC LABORATORIES OF DENISON UNIVERSITY" (*Jour. Sci. Labs. D. U.* 29, Art. 4, Dec. 1934). A second article was published by Kirtley F. Mather, one time editor of the JOURNAL, under the title "Later History of the JOURNAL OF THE SCIENTIFIC LABORATORIES OF DENISON UNIVERSITY" (*Jour. Sci. Labs. D. U.* 31, Art. 6, Dec. 1936).

The addresses of Drs. Croneis, Dorsey, Herrick and Wickenden delivered in commemoration of the semi-centennial of the founding of the Denison Scientific Association were made a part of our permanent record by publishing them in our JOURNAL (*Jour. Sci. Labs. D. U.* 32, Arts. 3–6, Aug. 1937).

The usual annual output of three numbers of our JOURNAL OF THE SCIENTIFIC LABORATORIES OF DENISON UNIVERSITY was maintained, as is shown below:

Vol. XXXI, Article 3, pp. 93–142, August, 1936.
The Newer Appalachians of the South (Part II): South of the New River; Frank J. Wright. 50 pp., 6 figs., 32 plates.
Vol. XXXI, Articles 4–6, pp. 143–259, December, 1936.
A Study of the Vestigial Air Bladder in the Darter (*Catonotis flabellaris rafinesque*); George David Morgan. 16 pp., 10 plates.
We Must Shape our New World (Commencement Address); Arthur Holly Compton. 11 pp.
Later History of the JOURNAL OF THE SCIENTIFIC LABORATORIES OF DENISON UNIVERSITY; Kirtley F. Mather. 25 pp.
Report of the Permanent Secretary of the DENISON SCIENTIFIC ASSOCIATION. 52 pp.
Vol. XXXII, Articles 1–2, pp. 1–131, April, 1937.
History of Theta Chapter of Ohio, Phi Beta Kappa (1911–1936); Willis A. Chamberlin. 69 pp., 2 figs.
The Tungsten Filament Incandescent Lamp; W. E. Forsythe and E. Q. Adams. 72 pp., 10 figs.

The increased number of exchange agreements with foreign institutions of learning, and the approaching exhaustion of our stock of some of the back issues of our JOURNAL, have made us print editions of 600 instead of 500 copies, as was our custom until recently. The number of requests for exchange of publica-

tions from Russian and Far Eastern institutions is noteworthy as indicating an intellectual awakening in that part of the world of which we in the Western Hemisphere are scarcely cognizant.

Respectfully submitted,

W. C. EBAUGH, *Permanent Secretary and Editor*

SUBJECT AND AUTHOR INDEX

Some suggested experiments for the graphic recording of speech vibrations; Robert James Kellogg. 14 pp., 6 figs.
The manipulation of the telescopic alidade in geologic mapping; Kirtley F. Mather. 46 pp., 13 figs.
The importance of drainage area in estimating the possibilities of petroleum production from an anticlinal structure; Kirtley F. Mather and Maurice G. Mehl. 4 pp., 2 plates.

Articles 9–12, pp. 147–224; May, 1920.....$0.75
Psychological factors in vocational guidance; Thomas A. Lewis. 10 pp.
The use of models in the interpretation of data for determining the structure of bedded rocks; Maurice G. Mehl. 12 pp., 6 figs., 2 plates.
Some suggestions for indicating drilling operations; Maurice G. Mehl. 6 pp., 3 figs.
The Kimmswick and Plattin limestones of Northeastern Missouri; Aug. F. Foerste. 50 pp., 3 plates.

Articles 13–16, pp. 225–329; September, 1921.....$0.75
Education for scholarship; William E. Castle. 9 pp.
The cytology of the sea-side earwig, Anisolabis maritima Bon., part 1; Sidney I. Kornhauser. 13 pp., 3 plates.
Notes on Arctic Ordovician and Silurian cephalopods; Aug. F. Foerste. 60 pp., 9 plates.
Revolution vs. evolution: the paleontologist renders his verdict; Kirtley F. Mather. 18 pp.

VOLUME 20

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